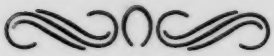
SPATSIZI

Report No. 4
July 1987

PERSPECTIVES ON INVENTORY OF CARIBOU IN BRITISH COLUMBIA



David F. Hatler

Ministry of Environment and Parks
Victoria, British Columbia

Spatsizi Association for Biological Research
Smithers, British Columbia

BC
WS
C
WS:R-14
1981
c.3

ISSN 0835-1848
ISSN 8829-7797

Province of B.C.
Ministry of Environment and Parks
Wildlife Branch
Victoria, B.C.

PERSPECTIVES

ON

INVENTORY OF CARIBOU

IN BRITISH COLUMBIA

By

David F. Hatler

Spatsizi Association for Biological Research Rep. No. 4

Wildlife Report No. R-14

July 1987

"Wildlife Reports are documents relevant to wildlife management in British Columbia but for various reasons have not been submitted or accepted for primary publication. Manuscripts submitted for publication in this form are not generally reviewed by referees outside the Branch. Copies may be obtained, depending on supply, from the Wildlife Branch, Ministry of Environment and Parks, Parliament Buildings, Victoria, B.C. V8V 1X5."

Canadian Cataloguing in Publication Data

Hatler, David F. (David Francis)

Perspectives on inventory of caribou in British Columbia

(Spatsizi Association for Biological Research rep., ISSN 0835-1848 ; no. 4) (Wildlife report, ISSN 0829-7797 ; no. R-14)

Co-published by the Spatsizi Association for Biological Research.

Bibliography: p.

ISBN 0-7726-0689-7

1. Caribou - British Columbia - Spatsizi Wilderness Provincial Park Region. 2. Mammal populations - British Columbia - Spatsizi Wilderness Provincial Park Region. I. British Columbia. Wildlife Branch. II. Spatsizi Association for Biological Research. III. Title. IV. Series: Report (Spatsizi Association for Biological Research) ; no. 4. V. Series: Wildlife report (Victoria, B.C.) ; no. R-14.

QL737.U55H374 1987 639.9'797357 C87-092144-4

Under the most rigorously controlled
conditions of pressure, temperature,
volume, humidity and other variables,
the organism will do as it damn well pleases.

A corollary of Murphy's Law,
A. Bloch (1979)

EXECUTIVE SUMMARY

Recent management plans and status statements for caribou in British Columbia have identified the need for better data on population composition and numbers, and for the development of improved and standardized inventory methods. This report describes inventory-related studies involving a sample of radio-collared animals in the Spatsizi Wilderness Park area of northern British Columbia, and discusses past and current inventory there and elsewhere in the province in relation to the telemetry findings. Highlights are as follows:

- The inventory development phase of the Spatsizi field studies involved documenting, through radio-tracking, seasonal animal distribution patterns as they relate to the potential for accurate and representative counts. The basic data included 840 radio locations, of over 40 different animals, on 59 tracking flights over a 4-year period. Variables considered were geographic location, elevation, habitat (degree of cover), slope direction, dispersion, group size, and animal visibility in particular pelage/background situations.

- Inventory evaluation was accomplished by monitoring the locations of radio-collared animals during visual census work, to document the proportion and characteristics of those missed.

- Based on the observed distribution, dispersion and relative visibility of Spatsizi caribou, as recorded during the inventory development studies, the best seasons for aerial census of caribou may be, in descending order, summer, early winter, and fall.

- Of the three annual periods that seem the most suitable for census of caribou in the Spatsizi area, only the fall rut count has been evaluated (1981-1984 and 1986). On average, fewer than half of the radio-collared animals, therefore possibly less than half of the population, were seen during visual surveys at rut time, apparently mostly because numbers of animals were not present in the designated, upland survey areas.

- Because the primary objective of the fall counts is documentation of recruitment, the most important result of the Spatsizi inventory studies was that females with calves were found in the fall rut concentration areas significantly less often than were those without.

- Consistent with the above result, fall recruitment expressed as calves:100 females was significantly higher in the sample of radio-collared animals than in visual survey samples.

- Overall, the fall counts were demonstrably biased against young-of-the-year, and possibly also against bulls. However, during the rut, many groups were too large to classify completely, resulting in a conflicting bias in resulting recruitment data, since there is an inverse relationship between group size and calf abundance.

- The rut appears to be a time when groups are particularly mobile and lacking in cohesion, so that it is difficult to predict even their day-to-day locations. Rather than migrating to particular locations to rut, as had been concluded previously, it appears that they may rut during fall migration.

- The general conclusion is that fall surveys appear to be of limited usefulness for determining caribou population status in Spatsizi Park, and probably in other areas of northern British Columbia.

- Most caribou population data for the Spatsizi area through 1975 were obtained through incidental observations scattered in both time and space. Attempts to interpret historical population trends have failed to fully consider the limitations of those data:

a) Recruitment - Representative samples are difficult to obtain. Small local samples, or cumulative duplications thereof, are not reliable indicators of overall population composition and, because of natural attrition of calf cohorts over time, direct comparisons between seasons do not appear to be valid.

b) Numbers - Direct comparisons of partial counts in local areas in different years do not appear to be valid indicators of the nature or extent of changes in numbers in the total population.

- Since 1976, caribou population data in the Spatsizi area have been obtained in more systematic and standardized fashion, by fall rut counts in specified locations, but the samples obtained were nevertheless biased in terms of population composition, and unreliable as indicators of population trend.

- Overall, it is concluded that the data available through 1987 are inadequate to confirm recent interpretations on rates and causes of caribou population changes in the Spatsizi area over the past 30-40 years.

- Throughout the province, caribou inventory generally involves use of a jet helicopter in an attempt to count and classify all animals in designated survey areas, usually defined by lower elevational or open-habitat limits. The primary difference in methodology among areas is the local timing of surveys:

a) Rut surveys are widely used in the northern half of the province, and may be subject in all areas to the same biases identified in the Spatsizi studies.

b) Winter surveys have produced the highest counts in many areas of B.C., especially in the deep snow-belt ranges of the "mountain caribou" ecotype. Winter may be the best season for surveys, because 1) Winter occurrence in open, upland habitats appears to be obligatory, in response to snow conditions, maximizing the proportion of animals available for counting and often minimizing the area in which they occur, and 2) Sightability of animals and tracks is best on a uniform snow background. A major drawback to scheduling surveys in winter is that the required upland distribution does not occur in all areas in all years. Although it may occur at any time, as snow conditions dictate, late

winter (end of March - early April) seems to be the most predictable.

c) Summer surveys were first employed in the Wells Gray Park area, southeastern B.C., based on the observation that on hot summer days caribou often seek high elevation snowpatches, where they may be readily counted. Because weather conditions vary from year to year, the results of those "snowpatch surveys" have been difficult to interpret. Nevertheless, summer surveys have potential because the most consistent occurrence of caribou above timberline during the Spatsizi telemetry studies was in summer.

d) Post-calving (early summer) surveys are important for some aspects of population dynamics studies, but are of limited usefulness for determining total population size and composition because of the under-representation of bulls and non-parous females in the survey areas.

- Some of the more mechanical aspects of gathering, presenting, and interpreting caribou population data are discussed, including minimum total counts versus sampling, expression of recruitment data, use of cumulative samples, classification of adult males, subjective expressions of survey reliability, and the concept of "baseline" values.

- Because caribou are mobile and wide-ranging, tending to occur in groups where segregation and differential behavior of various sex, age, and reproductive classes are common, it is difficult to define populations or to obtain representative samples.

- Telemetry studies in the Spatsizi Wilderness Park area have identified some features of life history that bear on inventory problems, and have provided a means of assessing the reliability of particular census activities and timing. The overall conclusion is that caribou inventory in the province has produced unsatisfactory data since it commenced in the 1970's. However, the applicability of the Spatsizi findings to other areas has yet to be established, and alternative methods are yet to be attempted and evaluated. Some recommendations for continued activities directed to assessing the status of caribou populations in British Columbia are presented.

ACKNOWLEDGEMENTS

The work reported here was conducted under the auspices of the Spatsizi Association for Biological Research (SABR), a non-profit, non-political organization dedicated to the task of securing the fundamental knowledge necessary to manage and preserve the large mammal ecosystems of the north. Commencing in 1980, the Association's research on caribou in the Spatsizi Wilderness Park area has been a cooperative effort. During the early years, funding or other direct assistance came from a variety of sources including B.C. Hydro and Power Authority, B.C. Ministry of Environment (Wildlife Branch), B.C. Ministry of Lands, Parks and Housing (Parks Branch), the MacLean Foundation, the Stikine Foundation for Wilderness Studies, the Koerner Foundation, the Vancouver Foundation, Dr. A.T. Bergerud (University of Victoria), the Guide-Outfitters Association of British Columbia, and anonymous private donations channeled through the World Wildlife Fund. Recently, most funding has come from Parks Branch, Wildlife Branch, the Canadian National Sportsman's Fund, and generous grants from Gulf Canada Ltd. This is the third major report on caribou research supported by the above sources.

A number of individuals have also made important contributions to the general SABR program. Former Executive Director Lamont Bassett generated and organized most of the funding through 1986. Continuing guidance and support has been provided by other SABR officers and directors, particularly John Kelsall, Irving Fox, Richard Stace-Smith, Don Eastman, Greg Jones, Jim Pojar, Bob Henderson, and Bob Harris. Eastman and Jones have been valuable supporters and trouble-shooters for the SABR program in liason with the provincial government, while Herb Green (Parks Branch) and Ray Halladay (Wildlife Branch) have also been helpful and supportive in that regard. Others to whom we owe our thanks are: David Pitt-Brooke, D.V.M., and Rick Page, biologist, for assistance during initial capture expeditions; Outfitters Ray and Reg Collingwood for their generosity and cooperation in providing facilities and information; pilots Tom Britton and Tom Brooks for interest and assistance beyond the call of duty, and for their good company.

For assistance in the preparation of this report, special thanks are due to technical editors Ian Hatter and Liz Stanlake, draftsperson Evi Coulson, and reviewers Greg Jones, John Kelsall, John Elliott, Rick Page, Doug Steventon, and Fred Harper.

TABLE OF CONTENTS

EXECUTIVE SUMMARY iii
ACKNOWLEDGEMENTS vi
LIST OF TABLES ix
LIST OF FIGURES x
LIST OF APPENDICES xi

1. INTRODUCTION 1

2. BACKGROUND 2
   2.1 CENSUS GENERALTIES 2
   2.2 ASPECTS OF CARIBOU CENSUS 3
      2.2.1 General 3
      2.2.2 Census of Woodland Caribou in Western Canada 5
   2.3 CENSUS DEVELOPMENT AND EVALUATION 6
   2.4 TELEMETRY IN BIG GAME CENSUS 7
      2.4.1 Use of Telemetry in Population Estimation 7
      2.4.2 Telemetry for Census Evaluation and Development . . . 8

3. INVENTORY STUDIES IN SPATSIZI PARK 9
   3.1 INTRODUCTION 9
   3.2 THE STUDY ENVIRONMENT 9
   3.3 METHODS 10
      3.3.1 Inventory Development 10
      3.3.2 Inventory Evaluation 10
         Fall Census ("Rut Counts") 11
         Evaluation Activities 11
   3.4 RESULTS AND DISCUSSION 11
      3.4.1 Inventory Development 11
         Elevation 13
         Vegetative Cover 16
         Aspect 19
         Dispersion 19
         Aggregation Patterns 21
         Visibility 24
         Summary and Synthesis 24
      3.4.2 Inventory Evaluation 26
         Sightability 26
         Representativeness 28
         Flight Considerations 35
         Rut Survey Timing 35
         Effect of Group Dynamics 37
         Minimum Count Versus Sampling 38
      3.4.3 Conclusions: The Utility of Rut Surveys 39

4. CARIBOU...DATA IN SPATSIZI PARK: A HISTORY AND ASSESSMENT 40
   4.1 INTRODUCTION AND RATIONALE 40
   4.2 HISTORY: 1905-1959 40

Table of Contents (continued)

4.3 DATA ON RECRUITMENT 41
4.3.1 Survey and Observation Objectives 42
4.3.2 Sample Size Effects 42
4.3.3 Duplication 43
4.3.4 Effects of Survey Location 43
4.3.5 Effects of Survey Timing 43
4.3.6 Conclusions: Recruitment Data 44
4.4 DATA ON NUMBERS 46
4.4.1 Differing Survey Objectives 46
4.4.2 Winter Distribution Effects 47
4.4.3 Effects of Sample Size (Partial Counts) 48
4.4.4 Effects of Survey Timing 49
4.4.5 Rut Counts, 1976-1986 50
4.5 SUMMARY: SPATSIZI CARIBOU POPULATION DATA 53

5. ASSESSMENTS OF CARIBOU INVENTORY THROUGHOUT BRITISH COLUMBIA . . . 54
5.1 BACKGROUND 54
5.1.1 General 54
5.1.2 Population Distinctions 54
5.1.3 Biological Factors Affecting Inventory 56
5.2 AREA ASSESSMENTS 57
5.2.1 Introduction 57
5.2.2 Rutting Aggregation Surveys 59
5.2.3 Winter Surveys 64
5.2.4 Summer Snowpatch Surveys 65
5.2.5 Post-calving Surveys 65
5.3 OTHER INVENTORY CONSIDERATIONS 65
5.3.1 Data Gathering 66
5.3.2 Data Presentation 66
5.3.3 Data Interpretation 68

6. CONCLUSION AND RECOMMENDATIONS 69

7. LITERATURE CITED 71

APPENDICES 81

LIST OF TABLES

1. Seasonal occurrence of radio-collared caribou at high elevation in the Spatsizi Wilderness Park area, British Columbia, 1980-1984 17

2. Caribou group sizes in the Spatsizi Wilderness Park area, British Columbia, October 1980 - March 1987 22

3. Seasonal potential for inventory of Spatsizi caribou in relation to some distributional and environmental variables 25

4. Aspects of distribution and sightability of caribou, as observed on fall census and census evaluation flights in the Spatsizi Wilderness Park area, British Columbia, 1981-1986 27

5. Distribution of radio-collared caribou during fall rut surveys in Spatsizi Wilderness Park, British Columbia 29

6. Comparative fall recruitment data between radio-collared and visual survey samples of caribou in the Spatsizi Wilderness Park area, British Columbia, 1981-1986. 32

7. A preliminary list of considerations for gathering and interpreting population data for caribou in British Columbia . . . 55

8. Seasonal considerations for gathering and interpreting caribou population data in British Columbia 58

LIST OF FIGURES

1. Locations of fall surveys for caribou in the Spatsizi Wilderness Park area, B. C. 12

2. Annual cycle of caribou in the Spatsizi Wilderness Park area, British Columbia 14

3. Elevation of radio-collared female caribou on 58 tracking flights, 1980-1984 15

4. Seasonal occurrence of radio-collared caribou in four categories of habitat, Spatsizi Wilderness Park area, B.C., 1980-1984 18

5. Minimum area of dispersion of radio-collared caribou located on tracking flights in the Spatsizi Wilderness Park area, British Columbia, 1983 and 1984 20

6. Frequency of caribou group sizes in the Spatsizi Wilderness Park area, B.C., October 1980 - March 1987 23

7. Summer - fall distribution of female radio-collared caribou relative to survey areas (shaded) in Spatsizi Wilderness Park, 1984 and 1986 31

8. Impact of data from Tomias Mountain on Spatsizi Park caribou calf percentages, 1977-1986 34

9. Caribou calf percentages recorded on surveys in Spatsizi Wilderness Park, B.C., 1977-1985 45

10. Counts of caribou on selected rut survey areas in Spatsizi Wilderness Park, B.C., as related to interpretations of population trends 51

11. Relationship of mid-1970's caribou recruitment data in British Columbia to the seasons of surveys 61

LIST OF APPENDICES

1. Criteria and standards for distinguishing the various sex and age classes of caribou for fall demographic studies in the Spatsizi Wilderness Park area, British Columbia 81

2. Details of caribou census and evaluation activities, Spatsizi Wilderness Park area, British Columbia, 1981-1986 82

3. Distribution and status of radio-collared caribou during rut surveys, 1981-1986, Spatsizi Wilderness Park and vicinity, British Columbia 84

4. History and description of observations and surveys producing data on caribou numbers and composition in Spatsizi Wilderness Park, British Columbia 87

5. Area-specific assessments of caribou inventory in British Columbia, as related to aspects of life history 89

PERSPECTIVES ON INVENTORY OF CARIBOU IN BRITISH COLUMBIA

1. INTRODUCTION

Caribou attained a high public profile in British Columbia in the late 1970's, following an extensive status assessment by Bergerud (1978a). Comparing results of a series of fall and winter surveys in 1977-78 with past observations and inventory results, he concluded that combined natural predation and human harvest had caused the species to decline in the province by 40 to 50% within the decade, and that the trend was continuing. Caribou research and management in British Columbia since then have largely reflected and responded to Bergerud's ideas and methods.

Subsequently, the British Columbia Fish and Wildlife Branch (BCFW 1979) estimated the population of caribou to be "between 10 000 and 20 000 animals". Despite the roughness of that estimate, they outlined several objectives and remedial strategies. The need for "better inventory" and for "...the development of new and standardized inventory techniques..." was acknowledged. Those needs have been reiterated in a recent status assessment of caribou in the southern half of the province (Stevenson and Hatler 1985).

Since October 1980, the Spatsizi Association for Biological Research (SABR) has conducted a radio telemetry study of caribou in the Spatsizi Wilderness Park area of northern British Columbia. The studies have addressed various information needs identified by the province, including those relating to inventory. The purpose of this report is to provide a review of caribou inventory, particularly as it has been practiced in British Columbia, and to report on progress of the Spatsizi studies. Unless stated otherwise, the Spatsizi findings cited in the following text are from Hatler (1986a). All caribou in British Columbia are considered to belong to the subspecies Rangifer tarandus caribou, or woodland caribou (Banfield 1961).

2. BACKGROUND

As used here, the term inventory refers to the process of gathering field data on animal distribution, numbers and/or population composition. In a previous paper (Hatler 1985), I emphasized the relationship between inventory and management, arguing that deficiencies in both quantity and quality of inventory are common. Management is largely a set of actions that attempts to promote and respond to changes in populations; therefore, one of the most important ingredients in the management process must be the information by which those changes are detected and recognized. Without such information at appropriate levels of accuracy and precision, managers can neither ascertain when management should be applied nor determine whether it has been successful. For research that attempts to relate population processes and status to specific variables, the situation is even more critical, involving less tolerance in the required inventory data than is the case for management.

Two kinds of inventory, the identification of functional caribou populations and the documentation of their seasonal movements and distribution, are needed in many areas of British Columbia. The methods for obtaining such information are known; they need only to be employed (Stevenson and Hatler 1985). However, there are no certain methods for gathering consistently reliable field data on numbers and composition of woodland caribou in their western range. Accordingly, the focus in the Spatsizi studies has been on "census", the general term applied to inventorying for population dynamics information.

2.1 Census Generalities

In most attempts to census or estimate a population, only a proportion of the animals present, even in sample units, is seen. A major consideration in development and evaluation of inventory methods is to determine the size of that proportion. Known populations and marked samples have been used either to evaluate methods (Bouffard and Hein 1978; Caughley 1977a) or to produce more refined population figures by ratio-estimation procedures such as the "Lincoln Index" (Davis and Winstead 1980; Rice and Harder 1977). Studies of known populations such as moose in enclosures (LeResche and Rausch 1974) or herds of domestic livestock (Caughley, Sinclair, and Scott-Kemmis 1976) showed the magnitude of aerial survey bias, and some of the contributing factors. Factors include variations among observers, who may differ in experience, competence and attention span; variations in visibility conditions on the

ground; and, human limitations in concentration and ability to perceive objects consistently under varying conditions of light, motion and distance (Caughley 1974, 1977a,b; Norton-Griffiths 1976).

Another aspect of census is the purely mathematical treatment of data. Sophisticated procedures have evolved to enhance precision and/or aid interpretation of data from the various census methods (Adams 1951; Chapman and Overton 1966; Paulik and Robson 1969; Anderson et al. 1979; Burnham, Anderson, and Laake 1980). However, mathematics has limitations in population estimation. That point is made repeatedly by Caughley (1977a), who noted that "Some analyses, although mathematically impeccable, require information that is difficult or impossible to collect in the field" or may be "...anchored on assumptions that have little or nothing to do with the realities of living things".

In an elegant paper devoted to the question of sample sizes required for various studies, Eberhardt (1978) concluded with a strong statement in support of "...research on census methodology on a broader front than presently exists". That opinion was also given by Davis and Winstead (1980) in noting that "...further progress...requires concentration on improvement of estimators but, more particularly, a detailed study of biases and the appropriateness of assumptions".

2.2 Aspects of Caribou Census

2.2.1 General

Banfield et al. (1955) confirmed the use of aerial surveys as "...the only practical means of obtaining big game population data in the vast regions of northern Canada". They described some of the initial efforts to assess populations of both caribou and moose with aerial transects, and experimented with some of the factors, such as width of transect, that affected results. Watson and Scott (1956) refined and increased the intensity of caribou counts in the Nelchina area of Alaska, providing an immediate three-fold increase in the population estimate. A few years later Siniff and Skoog (1964) achieved an even higher population estimate in the Nelchina Basin, using a stratified sampling procedure. Bergerud (1963) tested and refined winter transect counts for caribou in Newfoundland, and showed that snow cover affected the animals' distribution and greatly influenced census results. Although most studies cited above involved testing, evaluation, and refinement of procedures, none had the benefit of marked animals to assist in the assessments. In most

cases, the highest counts were considered the best and were the standards against which the other results were compared.

In a review of caribou biology, Bergerud (1978b) stated that "...because they live in open habitats, (caribou) are relatively easy to census". His subsequent summary of available methods, and list of population estimates for herds throughout the continent, indicate that most current caribou census technology is applicable to barren ground caribou (R. t. groenlandicus and R. t. granti) rather than to woodland caribou. Most problems associated with censusing barren ground caribou result from the immense areas and large group sizes often involved. The problem of area requires learning the seasonal ranges and general migration patterns of the herds involved to predict where and when census activities might best be employed, and using various sampling procedures (Heard 1985; Fong et al. 1985). The problem of numbers has been addressed with ratio comparisons involving marked animals of certain sex and age classes (Thomas 1969; Parker 1972) and with photographic techniques (Whitten 1985). Photography eliminates some observer bias, and results in higher local counts (Heard 1985).

An "aerial photo - direct count - extrapolation (APDCE)" census method (Davis, Valkenburg, and Harbo 1979) is currently in use in Alaska and some areas of northern Canada , although it is apparently not completely satisfactory. Davis, Valkenburg, and Harbo (1985) note that the APDCE system is the subject of continuing evaluation and research in Alaska, and that future modifications are likely.

Although caribou are theoretically "relatively easy to census" (Bergerud 1978b), the overwhelming evidence presented at a recent symposium (Meredith and Martell 1985) is that, even on open tundra and despite 40 years of trying, it is still not easy to census the animals accurately or precisely. Fong et al. (1985) found that helicopter surveys in sample quadrats generated higher population estimates than either fixed-wing or helicopter counts along sample transects, but that both types of surveys "...produced confidence intervals that rendered population estimates unsatisfactory for management purposes." Goudreault (1985) outlined some census problems and variable results for northern Quebec. Cameron et al. (1985) concluded that population estimates "...based on less than 10% coverage (area), may be little more than quantitative wild guesses". Perhaps the best example of the importance of reliable census information is Gates (1985) description of "the fall and rise of the Kaminuriak caribou population." That intensively studied population

was believed threatened in 1980, as indicated by a continuing downward trend in census data but, in 1982 and 1983, was found to contain about twice as many animals as had occurred at the reference peak in 1968.

There are no regularly used census strategies for woodland caribou (see review in Hatler 1983a), and given the wide range of ecological situations where that subspecies occurs, it is unlikely that any one strategy would be universally applicable. Generally, both survey areas and animal numbers are smaller than is the case for barren ground caribou. Therefore, the central problems with woodland caribou census are to identify when most of the animals are occupying habitats where they are most visible, and to minimize or correct for biases in the local representation of sex and age classes.

2.2.2 Census of Woodland Caribou in Western Canada

Most population inventory for western woodland caribou has been attempted through total counts rather than systematic sampling. In most cases the primary objective was to obtain data on population composition, with emphasis on recruitment. However, the data on numbers from those surveys have also been used in attempts to determine population trend, either by considering the totals seen as "minimum population estimates" or by subjectively expanding them to account for animals believed present but not seen (see Stevenson and Hatler 1985). Helicopters were preferred for most surveys, especially where population composition data were sought, although fixed-wing aircraft were used in a few cases where the area of coverage was extensive (Bergerud 1978a; Farnell and Russell 1984).

Survey timing has usually reflected local perceptions of when and where the animals may most readily be found. For populations whose annual range is fairly homogeneous, for example in boreal forest east of the Rocky Mountains, winter surveys have been the rule. In northeastern Alberta, Fuller and Keith (1981) surveyed after a fresh snowfall, to find animals by first locating tracks. Edmonds and Bloomfield (1984) conducted fall surveys in known rut areas for both upland and lowland dwelling groups of caribou in western Alberta, but obtained their highest total counts for both groups incidentally, when the animals were on winter range.

Census timing has varied in the heterogeneous mountains of British Columbia, where the general strategy has been to conduct surveys when the animals are in open habitats at or above timberline. In Wells Gray Park, most surveys were flown during a hot period in July when the caribou were expected to congregate at high elevation snow patches (Ritcey 1976, 1982). Recent surveys there (Ritcey and Stewart 1985), and in the Columbia Mountains 200 km farther southeast (Simpson, Hebert, and Woods 1984), have been in March when

the animals are in alpine parkland habitats. Late winter/early spring surveys have also produced the highest counts in some areas of northern British Columbia, for example in the Telkwa Mountains (Bergerud 1978a; Stevenson and Hatler 1985), and in Mount Edziza Provincial Park (Bergerud 1978a; Hatler, unpubl.). However, winter surveys have failed to find animals in other areas such as northern Tweedsmuir Park in the late 1970's (Hatter 1979) and several locations in northeastern British Columbia in February 1978 (Bergerud 1978a). Hatler (1986a) showed that Spatsizi caribou were conspicuous in alpine areas during some winters but, when snow conditions allowed, they remained dispersed in lowland forest, where census would be impractical.

Caribou use high elevation habitats most predictably during the snowfree months, June through October (Hatler 1986a), and census attempts then have been common. They include the previously mentioned July surveys in Wells Gray Park (Ritcey 1982), and a mid-July 1980 survey in the Wernecke Mountains, northern Yukon (Farnell and Russell 1984). Since 1979, most caribou surveys in the Itcha and Ilgachuz Mountains (Cariboo Region, central British Columbia) have been in June, within a week or two of calving (Stevenson and Hatler 1985).

Following the lead and advice of Bergerud (1978a), most caribou in the northern half of British Columbia are now censused during the fall rut period, when concentrations of animals may predictably be found on particular open alpine plateaus (Anonymous 1983; Jones 1984a; Hatter n.d.).

2.3 Census Development and Evaluation

Most biologists who conduct censuses become at least informally engaged in both development and evaluation. Casual evaluation may involve subjective statements such as "we believe we saw a large proportion of the animals", or "we believe we saw 85% of the animals". Development at that level often takes the form of such statements as "it was too soon after the snowfall", or resolutions such as "I'll never use that pilot again". The relationship between evaluation and development is obvious, the former affirming whether or not a particular survey went well and the latter describing factors that may have affected the observed results.

Many papers on caribou census have been concerned with evaluation and refinement of methods, but usually without the benefit of known populations or marked animals (e.g., Banfield *et al.* 1955; Bergerud 1963; Siniff and Skoog 1964). That appears to be generally true for most other species as well. Evans, Troyer, and Lensink (1966) and Bergerud and Manuel (1969) experimented with methods to obtain the best counts of moose, but the standards against

which their results were compared were high counts in which most of the animals were believed, but not known, to have been seen. The same was essentially true of Novak and Gardner's (1976) moose surveys. In their case, the test counts were from fixed-wing aircraft and the reference standards from a helicopter. Other observers have checked aerial counts of various kinds against ground counts, for example, in brown bear studies by Erickson and Siniff (1963), moose counts by Edwards (1954), surveys of sea ducks by Stott and Olson (1972), and sea otter studies by Samuel and Pollock (1981). In each case, the two methods were compared and correction factors applied to bring the two estimates closer together. Unfortunately, however, there was no way to determine how close the resulting adjusted estimates were to the true population figures.

Because it involves marked individuals that can generally be found at will, radio telemetry has attracted attention in census work and, as will be discussed, may prove particularly useful for development and evaluation.

2.4 Telemetry in Big Game Census

2.4.1 Use of Telemetry in Population Estimation

One of the problems inherent in population estimation by mark-recapture methods has been the assumption that the marked animals are in the count area on count day. Also, for visual markers, one must assume that no animals have died or emigrated from the study area, and that the number of animals originally marked is the number present. That may not be true except where the elapsed time between marking and recapture is short. Radio telemetry, which makes it possible to know how many marked animals are present, overcomes that problem. Some biologists have recognized and taken advantage of that feature of electronic marking in obtaining Lincoln Index estimates for study populations of various species including grizzly bears (Reynolds 1980; Wood 1976), moose (Mytton and Keith 1981; Boertje and Young 1982), and caribou (Fuller and Keith 1981).

Pearson (1975) and Schwartz, Franzmann, and Johnson (1982) used radio-collared animals as the basis for local population estimates of grizzly and black bears, respectively. In both cases, the marked bears and their regular companions (e.g, cubs) constituted the minimum known populations and unmarked but separately distinguishable animals observed in the study areas were added to those totals. Telemetry has also been used to help find the caribou herd to be counted (Valkenburg et al. 1985), and to study aspects of caribou ecology and behavior which, incidentally, might have important implications for development of locally appropriate census strategies. Among the latter

are studies on range affinities and migration patterns (Davis, Valkenburg, and Boertje 1982; Curatolo 1985), and on social cohesion (Miller et al. 1975).

2.4.2 Telemetry for Census Evaluation and Development

Surprisingly, telemetry has not been used often in evaluation or development of census procedures. None of 55 subjects indexed in a recent bibliography on wildlife telemetry (Patric, Shaughnessy, and Will 1982) is clearly related to census considerations, and only 1 of 844 papers listed (Parr and Scott 1978) is oriented in that direction. Because radio-collared animals not seen in a survey can nevertheless be located later, it becomes possible both to obtain some check on census results and to determine whether a particular census strategy is appropriate, considering the actual rather than expected distribution of the animals.

In studies of moose (Gasaway et al. 1978; Gasaway, DuBois, and Harbo 1981), and deer (Floyd, Mech, and Nelson 1979), telemetry has been used in development of census methods. The research teams used study blocks containing radio-collared animals to determine probabilities of sightings under various conditions. An alternative procedure is to treat the radio-collared sample as a representative population, as has been done in mortality studies of ungulates (Ballard, Spraker, and Taylor 1981). Preliminary inventory assessments for the Spatsizi area (Hatler 1983a) may be the only work of that kind to date.

3. INVENTORY STUDIES IN SPATSIZI PARK

3.1 Introduction

Heard (1985) identified four factors that affect the reliability of aerial survey data:

1) Observer Bias - Failure to see animals, due to a variety of physical factors that cannot be completely eliminated and can rarely be held constant.

2) Technical Problems - Procedural difficulties during surveys, e.g., defining and maintaining strip and quadrat boundaries, accounting for animal movements between sample units, and accurately counting animals in large groups.

3) Sampling Error - Accounting for variations in animal density among sample units.

4) Life History Assumptions - Inadequate or inappropriate surveys as a result of differences between the expected and the actual distribution and behavior of animals.

Field studies relating primarily to the fourth type of problem listed above were carried out in the Spatsizi Wilderness Park area of northern British Columbia. Results for that area may not be strictly applicable elsewhere in the province, but they may serve as a starting point for considering the general problem of how caribou population data can be consistently gathered and compared. The Spatsizi work is described below.

3.2 The Study Environment

The study area consists mostly of rolling uplands and plateaus in the upper Stikine River drainage, and includes the more rugged mountains and associated valleys surrounding the headwaters of the Skeena and Nass Rivers. Constituting more than 15 000 km^2 of pristine, essentially roadless country, the area occupied annually by the Spatsizi caribou is diverse both in topography and in vegetative cover. For census opportunities, there are extensive areas of alpine tundra and subalpine shrub, most between 1500 and 2000 m, where caribou commonly occur and are relatively visible. There are also extensive areas of coniferous forest (1000-1500 m), which the animals use regularly, and in which they may often be effectively hidden (see also Hatler 1983a).

The local climate, as described by Schaefer (1978), is characterized as having "long, cold winters and short, cool summers with moderate precipitation

which is well distributed throughout the year". Precipitation averages about 400-500 mm annually in the valleys, with up to 900 mm in the mountains. Mean annual temperatures are below 0^{o} C, and more than half of the precipitation indicated falls as snow. Climatic factors appear to affect both caribou numbers and census opportunity (Hatler 1986a).

3.3 Methods

3.3.1 Inventory Development

The primary field data included 840 radio locations, of over 40 different caribou, on 59 radio-tracking flights between November 1980 and November 1984 (Hatler 1986a). Each radio contact was considered in terms of its potential to contribute data in a visual aerial survey. In effect, for each radio location the question was asked: "If one were conducting a census at this moment, what would be the likelihood of locating, counting, and classifying this particular animal or group of animals?" The variables considered, all in relation to some period in the annual cycle, were geographic location, elevation, broad habitat types (degree of cover), slope direction, dispersion, group size, and animal visibility as related to pelage and background color contrasts.

3.3.2 Inventory Evaluation

Caughley (1977a) noted that "...to determine how well a sampling system and analysis copes with a real population, we must know the exact number of animals in that population. And to determine why it copes well or badly we must know where each animal was standing at the time of survey". He states further that "this information is never available". However, if the sample of radio-collared animals is defined as a population, it is possible to know both the numbers that are present and at least their approximate locations during a survey. At Spatsizi, the collared animals were monitored during the course of visual census work in 1981-1984 and in 1986, to determine the proportion and characteristics of those that were missed.

Because the base color of our radio collars was white, which was difficult to see against the white-necked, fall pelage of caribou, the collars were initially wrapped with colored tape to make them more conspicuous. However, by 1984 the tape had worn away on many and some collared caribou could not be easily recognized from the air. The animals were closely monitored in that year, and a collared one was assumed to have been seen by the census crew if the group in which it occurred was seen.

It is acknowledged that a sample of 25 or fewer collared animals is small in relation to the total Spatsizi population, about 1.3-1.7% assuming

1500-2000 animals (Jones 1985a). However, that sample has provided the only objective inventory evaluation data available in the province.

Fall Census ("Rut Counts") - As recognized by Osmond-Jones et al. (1977), there are three major caribou rutting areas wholly (Caribou Mountain and Tomias Mountain), or partly (Edozadelly Mountain) within Spatsizi Park (Fig. 1). Those areas are traditional in the sense that concentrations of rutting caribou usually occur in their open uplands in late September to mid-October. Rut counts, conducted within the boundaries of one or more of those three areas in any given year, are largely limited to open shrub or alpine habitats at or above 1525 m. A jet helicopter, carrying two or, usually, three experienced observers, is employed in a combination of flight speed, elevation, and pattern judged to be appropriate for the topography and visibility. The objective is usually to count and classify all caribou present. For population composition data, the priorities are to determine the number of young-of-the-year and mature males, both in proportion to the total sample. Secondarily, an effort is made to obtain ratios of other classes, including adult females and young males. The classification criteria and standards used are given in Appendix 1. The timing, nature and staffing of Spatsizi census surveys since 1981 are listed in Appendix 2.

Evaluation Activities - Although the general procedures for evaluating the rut count have remained constant, some practical factors resulted in variation in the extent of activities from year to year (see Appendix 2). The most thorough evaluations were in 1981, 1984, and 1986, when the collared sample was 9, 27, and 21 caribou, respectively. In those years, a helicopter was available to assist in determining the maternal status of collared females not seen in either the census or fixed-wing tracking flights.

In 1982, there were only four collared animals and one of those was missing at rut time, thus little evaluation effort was warranted. A number of problems combined to reduce the effectiveness of the 1983 work (Appendix 2), and no evaluation studies could be undertaken in 1985.

3.4 Results and Discussion

3.4.1 Inventory Development

Most wildlife inventories are "...glimpses within the full-time lives, 365 days a year, of the animals". Just as the sample frames in an advertisement for a movie have to be carefully selected if they are to impart to a potential customer a representative view of what the movie is about, so

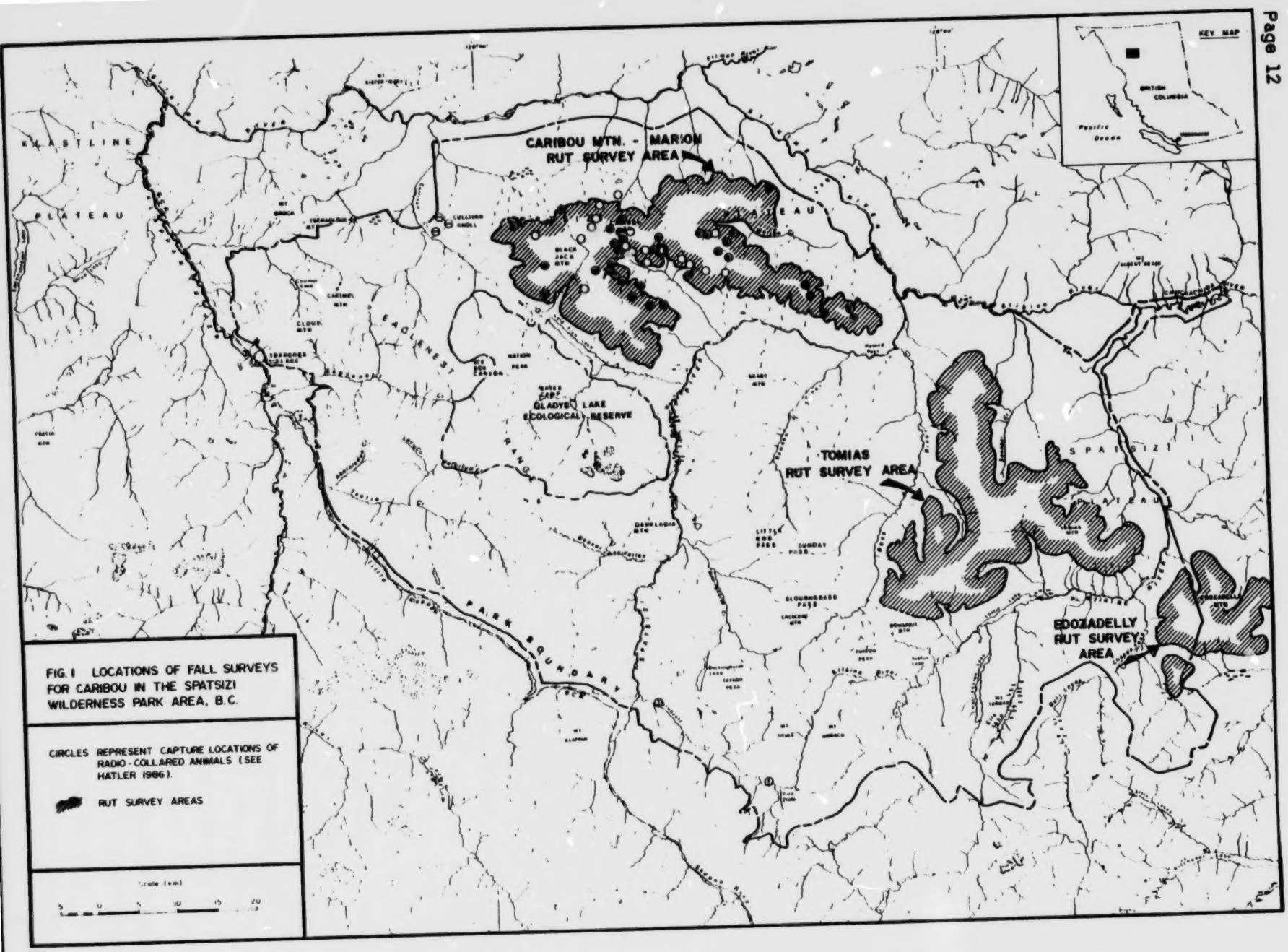


FIG. 1 LOCATIONS OF FALL SURVEYS FOR CARIBOU IN THE SPATSIZI WILDERNESS PARK AREA, B.C.

CIRCLES REPRESENT CAPTURE LOCATIONS OF RADIO-COLLARED ANIMALS (SEE HATLER 1986).

RUT SURVEY AREAS

does the moment of inventory have to be carefully selected to provide significant and representative information about a subject population (Hatler 1985).

The underlying focus for development of caribou census at Spatsizi is potential census timing in relation to predictable events in the animals' annual cycle. Figure 2 depicts the annual cycle of Spatsizi caribou as it was understood after 4 years of radio tracking (Hatler 1986a). The following paragraphs discuss selected variables in terms of the life history periods indicated.

Elevation - Figure 3 summarizes elevation data for approximately 700 radio locations of female caribou between November 1980 and October 1984. The general pattern was a gradual descent from relatively open subalpine areas at 1500-1600 m in November, to about 1300-1400 m through April, followed by a drop to the lowest mean elevation of the year, under 1200 m, in May. Females then moved upslope in late May or early June, occupying areas as high as 2150 m in June and July but averaging about 1725 m during those months in 1982-84 and 100 m lower in 1981. The animals generally dropped to somewhat lower elevations in late summer and fall, averaging about 1600 m but mostly remaining above timberline, and then again commenced the descent to winter range.

The most unusual elevation distribution during the study was in 1980-81, when females generally remained at high elevation throughout the winter and then occupied somewhat lower than average elevations in June and July (Fig. 3). That distribution was explained by climatic factors, including a 330% heavier than normal snowfall in December and a late spring (Hatler 1986a).

Sample sizes for males were small, averaging just 2.5 radio locations per flight as compared to 12.0 for females over the 4-year period. Conclusions for males must therefore be tentative, but their pattern of elevational distribution was similar to that of females for most of the year. The most conspicuous and regular difference was during the calving period, when 78% of all female locations but only 22% of male locations over the four study years, were above 1500 m (Table 1). Males moved upslope after that time, remaining high with the females throughout the summer and early fall. However, as shown in Table 1, they were less prone than females to be found in both subalpine and alpine areas during the pre-rut and rut periods. Males may be more mobile than females during rut, resulting in a greater likelihood of encountering them crossing valleys and lowland areas during tracking flights at that time.

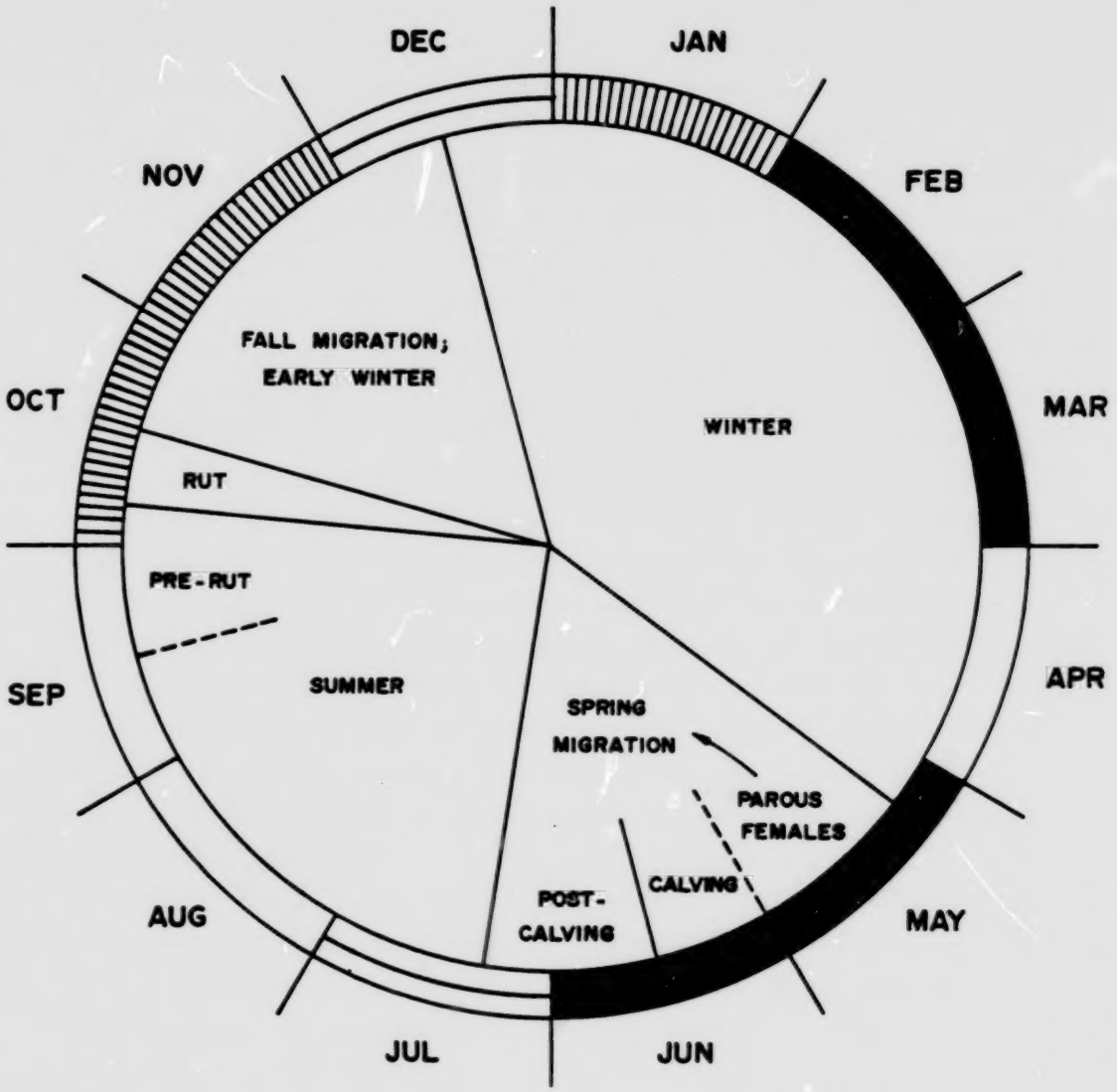
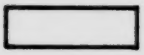
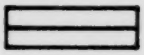


FIG. 2. ANNUAL CYCLE OF CARIBOU IN THE SPATSIZI WILDERNESS PARK AREA, BRITISH COLUMBIA.

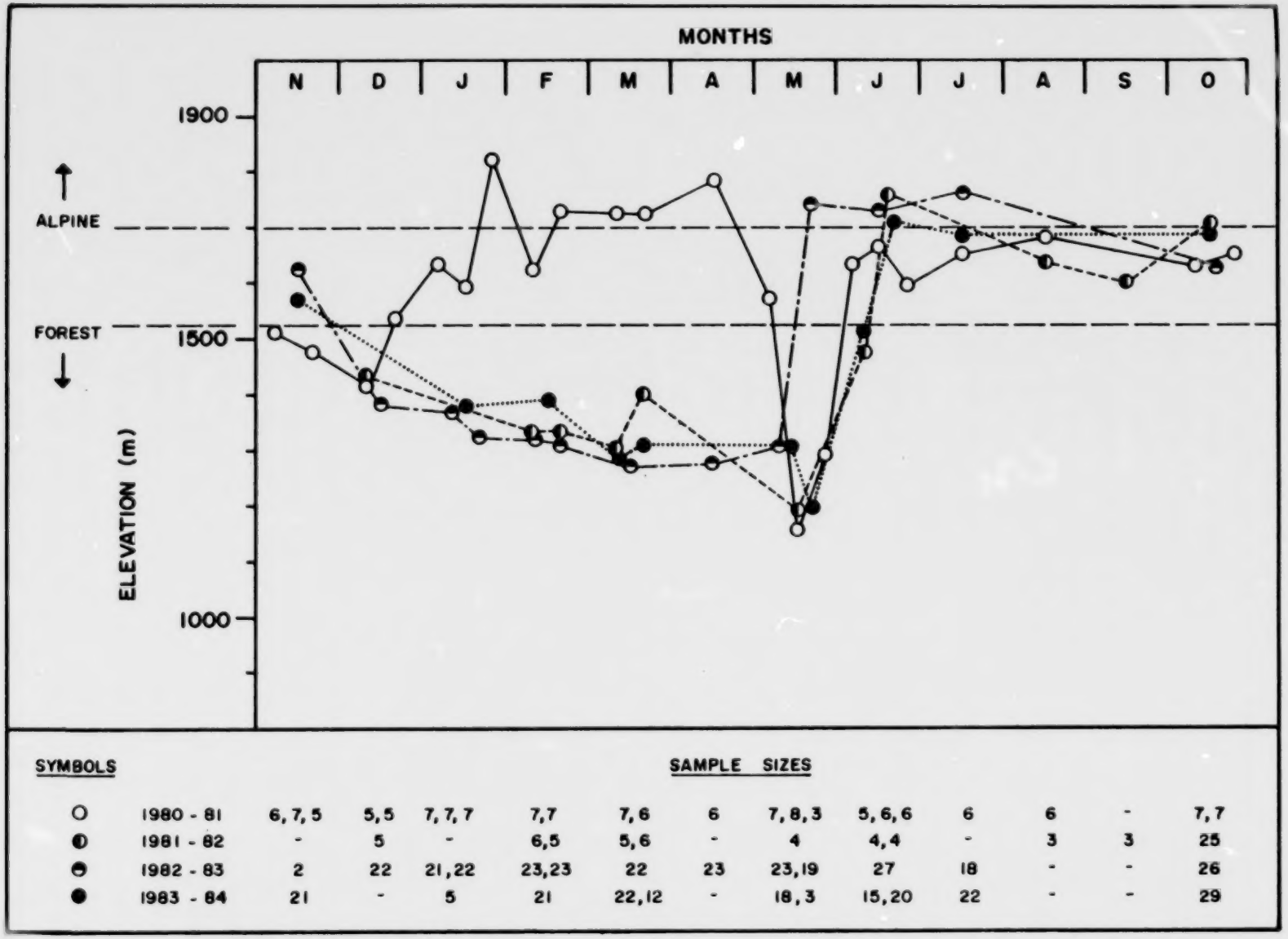
Outer ring shows number of radio-tracking flights in each month over the four-year period 1980 - 84:

1 - 2 

5 - 6

3 - 4 

7+



SYMBOLS		SAMPLE SIZES											
○	1980 - 81	6,7,5	5,5	7,7,7	7,7	7,6	6	7,8,3	5,6,6	6	6	-	7,7
◐	1981 - 82	-	5	-	6,5	5,6	-	4	4,4	-	3	3	25
◓	1982 - 83	2	22	21,22	23,23	22	23	23,19	27	18	-	-	26
●	1983 - 84	21	-	5	21	22,12	-	18,3	15,20	22	-	-	29

Figure 3. Elevation of radio-collared female caribou on 58 tracking flights, 1980-1984, in the Spatsizi Wilderness Park area, British Columbia. Each plotted point is the mean for the number of animals (listed under sample sizes) observed on each flight (from Hatler 1986a).

Males may use higher elevation areas than females after the rut, particularly in November and December but possibly throughout the winter. An exception to that pattern was in 1980-81. Both sexes moved to alpine areas shortly after a heavy snowfall in December, but although six of seven collared females remained in that habitat for the rest of the winter, all three males moved downslope in early February. One of those died at about 1200 m in late March, one remained and survived in lowland forests for the remainder of the winter, and the third moved back into alpine areas with the females in early March.

Assuming a relationship between habitat features and elevation typical for the Spatsizi area, the broad inventory implications of the observed elevational distribution (Fig. 3 and Table 1) are as follows:

- In most years caribou cannot be counted between December and mid-June.
- During some winters, snow conditions may force a high elevation distribution in which a large proportion of the animals may be counted.
- The consistently highest frequencies of occurrences above 1500 m, both sexes considered, are during the snowfree months, and particularly from about July through mid- to late September.

Vegetative Cover - Although the elevation of a radio location indicated the probable habitat, there was some local variation. In particular, some north-facing slopes regularly used by caribou had extensive sparsely forested habitats, such as muskeg, at elevations below 1500 m. Figure 4 depicts the seasonal frequency of collared caribou occurrence in four broad habitat categories over the 4-year study. Consisting only of low herbaceous plants or bare ground, mostly above 1700 m, the alpine category offers no cover to hide caribou from aerial observers. It was the most frequented habitat type from June to October. The subalpine shrub type, used commonly during the rut and predominantly in early winter, consists mostly of Betula glandulosa and Salix sp., with occasional scattered conifers (mostly Abies sp.) in some areas. It is sometimes high and dense enough, especially when in leaf, to provide concealing cover for animals, particularly bedded ones.

Coniferous forest had the largest frequency of use by caribou in the Spatsizi area, 46% of all radio locations from 1980-84. That is a major reason why woodland caribou are difficult to inventory both there and elsewhere across their range. As the elevation data suggest, and Figure 4 confirms, most forest occurrences were in winter, although there were some records in every season. Local forests differ in cover characteristics; some

Table 1. Seasonal occurrence of radio-collared caribou at high elevation in the Spatsizi Wilderness Park area, British Columbia, 1980-1984. Seasons are as defined by Hatler (1986a). Elevations above 1500 m are mostly above timberline, in subalpine shrub or alpine tundra habitats; those above 1700 are mostly in tundra.

	Number (N) and Frequency (%) of Radio Locations[b]									
Seasons[a]	1980-81		1981-82		1982-83		1983-84		All 4 Years	
Elevation	N	%	N	%	N	%	N	%	N	%
Early Winter	27		0		68		23		118	
1500 m +		56		-		72		87		71
1700 m +		19		-		37		0		25
Winter	89		32		158		66		345	
1500 m +		72		31		5		9		26
1700 m +		57		19		<1		0		17
Spring Migr.	10		4		26		22		62	
1500 m +		0		25		12		5		8
1700 m +		0		25		0		0		2
Calving	12		4		53		42		111	
1500 m +		42		50		77		69		69
1700 m +		17		25		57		36		43
Post Calving	16		4		1		0		21	
1500 m +		88		75		100		-		86
1700 m +		25		75		0		-		33
Summer	14		3		21		24		62	
1500 m +		100		100		100		88		94
1700 m +		57		33		71		50		58
Pre-Rut/Rut	17		3		28		35		83	
1500 m +		82		100		86		89		87
1700 m +		53		0		25		34		34

[a]Season dates: Early Winter (16 Oct-15 Dec); Winter (16 Dec- 6 May); Spring (7-28 May); Calving (29 May-15 Jun); Post-calving (16 Jun-15 Jul); Summer (16 Jul-25 Sep); Pre-Rut/Rut (26 Sep-15 Oct).

[b]Results shown are for both sexes combined, although about 85% of the total locations in the sample were for females.

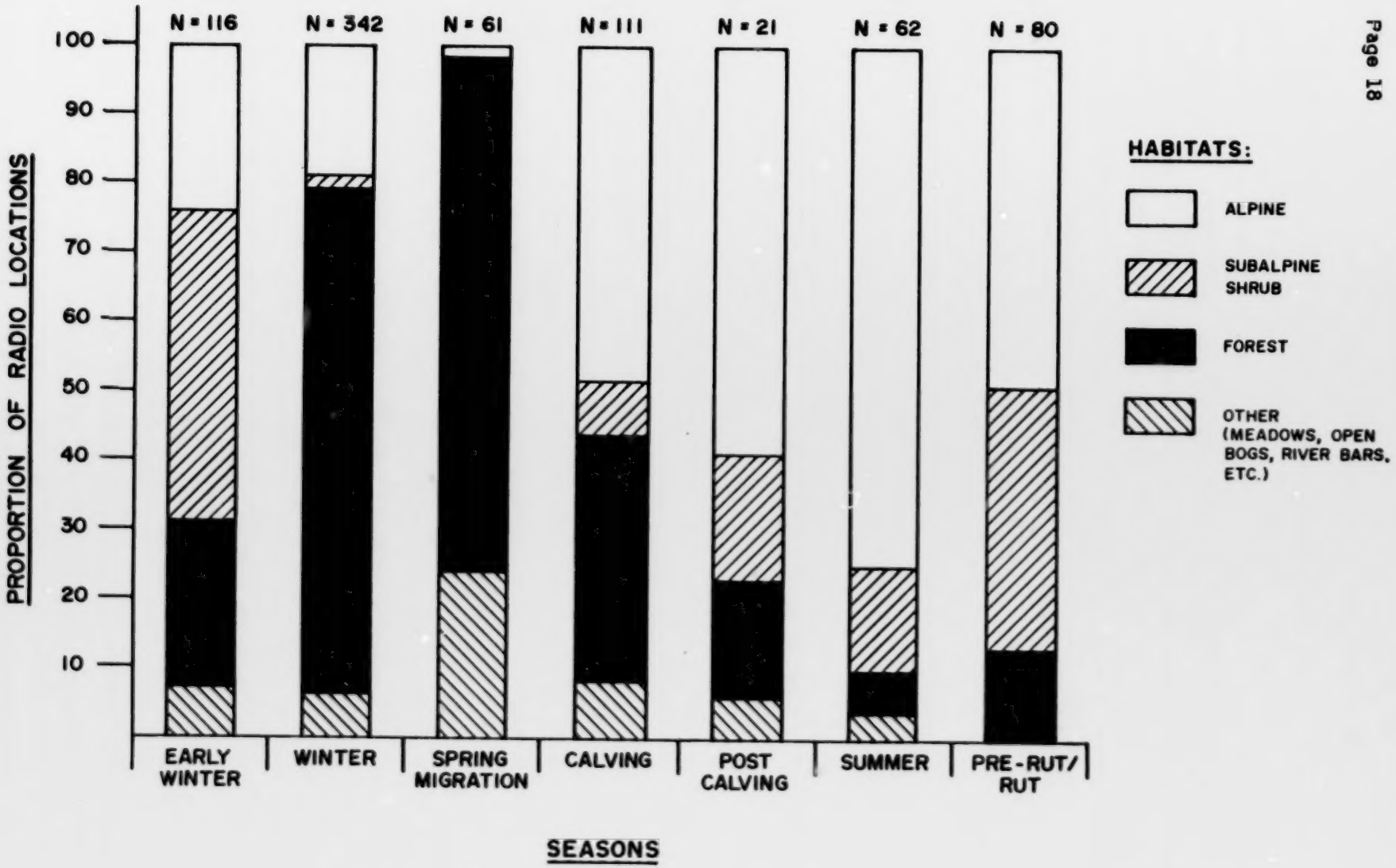


Figure 4. Seasonal occurrence of radio-collared caribou in four categories of habitat, Spatsizi Wilderness Park area, B.C., 1980-1984.

at high elevation and on poorly drained sites are sparse and open so that animals using them are relatively visible.

The collared Spatsizi caribou were also found in lowland habitats other than conifer-dominated forest, but such occurrences constituted only 7% of all radio locations recorded. Use of such habitats, which included deciduous forest, was documented in every seasonal period except pre-rut/rut. The heaviest use was in late winter and early spring, particularly in May, when the animals were seeking new green growth in bogs, riparian and lacustrine meadows, and slide areas (Fig. 4). In the context of inventory, a major feature of the "other" category of habitats was that they were more open and offered better visibility of adjacent forest. Figure 4 provides a visual summation of caribou occurrence, by season, in the three non-forest categories of habitat where they are reasonably visible for census.

Aspect - During the 4-year study, more than half of the locations for radio-collared caribou were on north-facing slopes, about 35% were on south-facing slopes, and fewer than 20% faced either east or west. Although that may imply a degree of predictability as to location, there were seasonal, annual, and sexual differences. The highest combined frequency of occurrence for females was on north slopes in all months except June, although there was some variation to that pattern in some years. For example, there was an equal or much higher use of south-facing slopes during the first two (deeper snow) winters, and an equal or greater use of north slopes in June following those two winters. Use of east or west slopes did not predominate in any of the 48 months studied, but the most uniformly equal distribution on all four slope directions was during the summer and fall months (June through October). During winter, occurrences were more strongly clumped on north and/or south slopes.

The sample of males was too small for annual comparisons, but the combined, 4-year data showed a seasonal slope distribution essentially parallel to that of females during the winter, but with greater use of south- and west-facing slopes from April through June. Males were equally distributed on all slopes in October. As with females, males were not found on east- or west-facing slopes most often in any month.

Hatler (1983a) concluded that "...the inventory biologist hoping to eliminate the necessity for observing all sides of the mountain will find little...encouragement here". Observations over three more years did not change that conclusion.

Dispersion - For efficiency and economy, the extent of the area to be surveyed must be considered. Figure 5 illustrates the pattern of dispersion

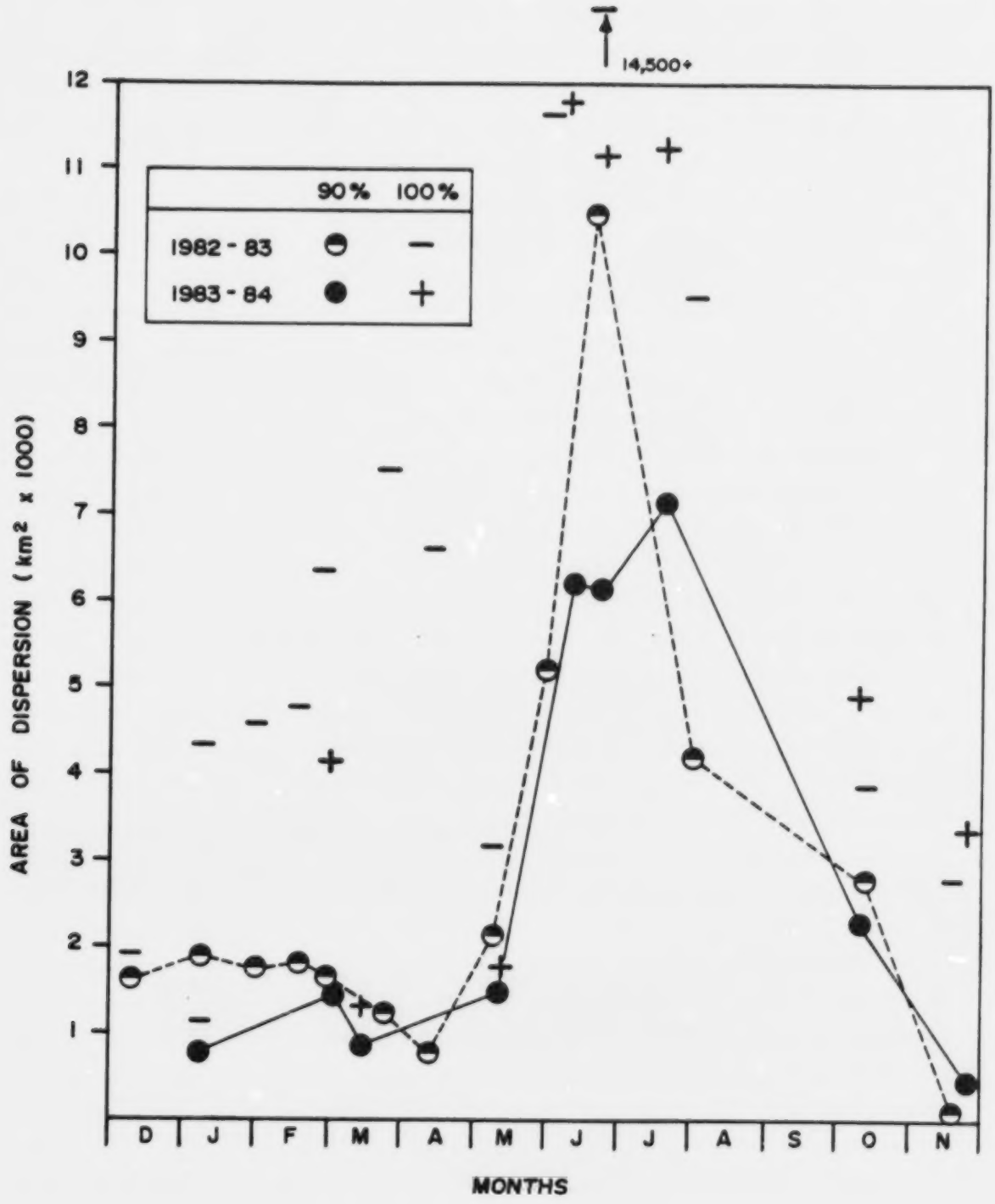


Figure 5. Minimum area of dispersion of radio-collared caribou located on tracking flights in the Spatsizi Wilderness Park area, British Columbia, 1983 and 1984. Both the total implied area and the 90% area (after exclusion of the most extreme 10% of the observations) are shown (from Hatler 1986a).

in the Spatsizi area during the 2 years when there were more than 25 collared animals. The general pattern was similar for both years, and was consistent with expectations based on an analysis of movements. Most of the animals, with numerous uncollared companions, occupied an area of less than 2000 km^2 from early December through early May, when movement was minimal. They then dispersed to an immense area of over 10 500 km^2 in June 1983 and at least 6000 km^2 at the same time in 1984. By the time of the October rut surveys in both years, most of the animals had withdrawn to an area of less than 3000 km^2 and, surprisingly, by the last half of November most were within an area of less than 500 km^2 in the vicinity of Caribou Mountain.

Despite differences in visibility in different seasonal habitats, census or sampling efforts would require more time and money during the May through September period of dispersion than during October through April.

Aggregation Patterns - Considering both the Spatsizi data and results from other areas, Hatler (1986a) concluded that the general aggregation pattern for woodland caribou is the same in most areas, despite local differences in habitats and population sizes. The smallest groups are found in spring - early summer; there is a peak in fall, and a decreasing trend in group size through the winter. As with other variables examined here, the most conspicuous departure from that pattern has been when heavy snow forced the animals to concentrate on windblown, upland habitats. The largest aggregations recorded in the 4-year Spatsizi study were during the deep snow winters of 1980-81 and 1981-82.

Data collected since 1984 generally confirm the patterns described above, although there is considerable statistical variation within any one time period (Table 2). The fall peak in mean group size results both from larger maxima (Table 2) and from increased frequency of the larger groups (Fig. 6).

Although grouping patterns are reasonably consistent and predictable, their implications for inventory are not fully understood. Large groups are more conspicuous than small groups, and the presence of large concentrations suggests a smaller time and budget requirement for tallying a given number of animals. On the other hand, accurate counts and classification are difficult among large groups, and the sex and age composition of large groups may not represent that in the total population (Ramey 1984--rut counts; Hatler 1986a--post-calving; see also, Section 3.4.2, this report). Finally, when group sizes are large the statistical consequences of missing some groups may also be large.

Table 2. Caribou group sizes in the Spatsizi Wilderness Park area, British Columbia, October 1980 - March 1987.

	Sample (N)	Caribou Group Sizes Range	Mean[a]	S.D.
JANUARY	105	1-43	9.2	8.3
FEBRUARY	102	1-100+	9.6	14.1
MARCH	136	1-100+	10.7	15.2
APRIL	34	3-80	17.6	18.0
MAY	47	1-50+	5.0	10.2
JUNE	203	1-28	3.2	3.0
JULY	146	1-55	6.4	7.7
AUGUST	31	1-16	4.5	3.8
SEPTEMBER	8	2-24	11.0	7.3
OCTOBER	490	1-232	14.7	19.2
NOVEMBER	105	1-48	10.0	7.5
DECEMBER	71	1-27	6.4	6.5
ALL MONTHS	1478	1-232	10.0	14.3

[a] Numbers with "+" (e.g., 50+), indicate estimates of minimum group size; means are calculated on the basis of those minimum values, thus are conservative; fewer than 5% of the groups represented were such estimates.

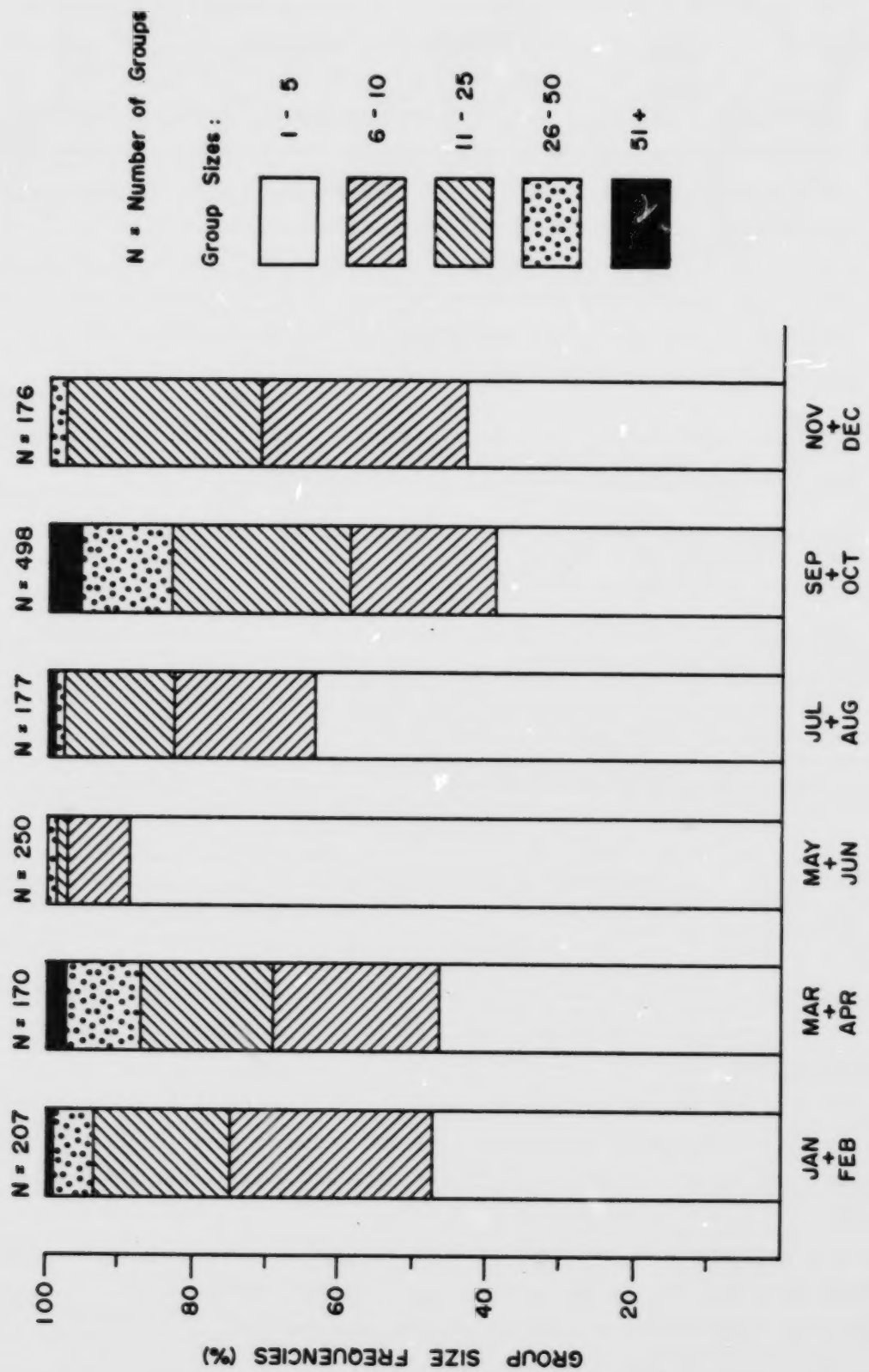


Figure 6. Frequency of caribou group sizes in the Spatsizi Wilderness Park area, B.C., Oct. 1980 - March 1987.

Visibility -Visibility of caribou on particular backgrounds has not been studied, but the Spatsizi work has provided considerable practical experience. Telemetry crews in fixed-wing aircraft failed to see more than half of all radio-located caribou, even though three or more low level passes were usually made at a signal location before a search was abandoned. Most such failures were over coniferous cover, but they also occurred over more open habitats. Often animals in open areas were seen only after persistent searching. Attempts to see caribou at radio signal locations were more successful from helicopters, especially in open habitats, but were still difficult in some lighting and background situations.

Following are some subjective assessments of relative visibility on a seasonal basis, all assuming good light in non-forested habitats:

- Spring to Early Summer: Pelage of many caribou is tawny and patchy, and may be difficult to see against the light browns and high contrast, patchy snow situations prevalent in uplands.

- Summer: Animals are in darkest pelage, and may show up well against the greens and light browns of alpine areas; there is usually less snow and less intense contrast.

- Fall, through Rut: Animals are in conspicuous pelage that shows up well against most snowfree or continuous snow backgrounds, but may be well camouflaged in patchy snow situations.

- Early Winter: Pelage is the same as in fall, and with the same advantages. Snow cover, usually continuous, greatly reduces the potential for camouflage, and fresh tracks are an additional aid to finding animals.

- Winter: Pelage becomes progressively lighter, but the continuous snow background provides the same benefits as in early winter; longer accumulation of tracks may reduce the potential for finding animals by tracking.

Summary and Synthesis - Our development work has tried to identify when and where caribou can best be inventoried. Table 3 is an attempt to summarize that work quantitatively. It provides a numerical ranking, by season, for each of the six variables discussed above. Each variable is given equal weight in Table 3 although, in practice, some are probably more important than others. The rankings are consistent with our data and experience, but are not unequivocal.

Table 3 suggests that the best seasons for aerial inventory of caribou in the study area may be, in descending order, summer, early winter, and the rutting period. Comparative evaluation studies are required.

Table 3. Seasonal potential for inventory of Spatsizi caribou in relation to some distributional and environmental variables. The rankings, on a scale of 1 (poor) to 7 (best), are derived from data and observations during long term radio-tracking studies (Hatler 1986a). Highest ranks are for openness of habitats, predictability of occurrence, smallest group sizes and areas of dispersion, and most distinct pelage-background separations.

	Relative Seasonal Ranks[a]						
Variables	Early Winter	Winter	Spring Migration	Calving	Post-Calving	Summer	Pre-rut/ Rut
Elevation	5	2	1	3	4	7	6
Veg. Cover	4.5	1	2	3	4.5	7	6
Aspect	4	4	4	4	4	4	4
Dispersion	7	6	2	2	2	4	5
Aggregation	4	2	2	7	6	5	2
Visibility	7	6	2	2	2	5	4
Mean Ranks	5.3	3.5	2.2	3.5	3.8	5.5	4.5

[a]Ranks judged equal (ties) are shown as the mean of combined potential scores, e.g.,two seasons tied for fourth, as under Veg. Cover, would be fourth and fifth if not tied, hence the rank shown is 4+5/2 = 4.5.

3.4.2 Inventory Evaluation

The two components of census evaluation that received the greatest emphasis were "sightability" and "representativeness". Analysis of sightability involves considering whether all the animals one hoped to count on a particular survey could actually be seen. Representativeness focuses on whether the sample of animals counted had the same sex and age composition as those that were missed. Other important aspects of the census evaluations include consideration of procedures, data interpretation, and survey efficiency in terms of costs.

Sightability - Fall surveys in Spatsizi Park are carried out in one or more of three open, upland rutting areas, on the assumption that most of the park population concentrates there during the rut. The objective is to count all of the animals occurring in each of the survey areas sampled (Jones 1985a). Table 4 indicates how well that objective was met during five fall surveys in the Spatsizi Park area (see also Appendix 3).

There are two primary considerations in relation to sightability: 1) the proportion of animals present that are potentially visible; 2) the proportion of those visible that are actually seen. Table 4 shows three levels of analysis pertaining to those considerations. The first addresses the assumption that most Spatsizi caribou are in the three designated survey areas at rut time. Although local managers do not now believe that assumption to be true (Jones 1985a; pers. comm.), it is foundational in references to Spatsizi caribou populations in several important publications (Bergerud 1978a; Bergerud and Butler 1978; Bergerud 1983; Bergerud, Butler, and Miller 1984; Bergerud and Elliott 1986).

As shown, the proportion of collared animals actually on or near the survey areas varied from about one-half (1982 and 1983) to three-quarters (other 3 years). Over 5 years, an average of 33% of the collared caribou were not in the survey areas at survey time, thus they were not available for counting under the census strategy employed. The absent collared animals were usually accompanied by numbers of uncollared animals, thus their absence from the survey areas was apparently not due to bias associated with the collared sample. Although the sample was small, there was an indication that males were more likely than females to attend the survey areas.

Of the collared animals present on the survey areas, not all occupied open alpine or subalpine habitats at survey time except in 1982, when the collared sample was small (N = 3). On average, about three-fourths of the collared animals on the survey areas were in the open, and therefore actually available for counting.

Table 4. Aspects of distribution and sightability of caribou, as observed on fall census and census evaluation flights in the Spatsizi Wilderness Park area, British Columbia, 1981-1986. Data under "Present" and "In Open Habitats" are for radio-collared animals (F-Female, M-Male, T-Total) detected on the Caribou Mountain, Tomias Mountain, and Edozadelly Mountain rut survey areas at survey time. "Census success" includes occurrences of collared animals away from the survey areas.

Years	Collared Caribou F	M	T	Present Females No. (%)	Males No. (%)	Total No. (%)	In Open Habitats Available[a] No. (%)	Seen No. (%)	Census Success Valid Sample[b]	Seen No. (%)
1981	7	2	9	5 (71)	2(100)	7 (78)	5 (71)	5(100)	8	5 (63)
1982	3	0	3	2 (50)	0(-)	2 (50)	2(100)	1 (50)	3	1 (33)
1983	24	4	28	13 (54)	2 (50)	15 (54)	10 (60)	8 (80)	25	8 (32)
1984	22	4	26	15 (68)	4(100)	19 (73)	14 (74)	13 (93)	26	13 (50)
1986	21	1	22	15 (71)	1(100)	16 (73)	14 (88)	9 (64)	22	9 (41)[c]
81-84[d]	56	10	66	35 (63)	8 (80)	43 (65)	31 (72)	27 (87)	62	27 (44)
ALL	77	11	88	50 (65)	9 (82)	59 (67)	45 (76)	36 (80)	84	36 (43)

[a]Theoretically available for counting, by virtue of location and habitat.

[b]Excluding collared animals that were not seen because they were in rut survey areas not surveyed completely.

[c]Two animals were detected near the boundaries of survey areas before the survey, but were not seen or contacted after the survey; if they were actually seen, but not recognized as collared, the census success for 1986 was 50% and the 5-year average was 45%.

[d]In 1986 the census crew had prior knowledge of some animal locations from a radio-tracking reconnaissance flight, thus the proportion of collared animals may have been biased upward. The separate 1981-84 totals are provided on that possibility.

Among those available, as described above, 80% were seen over the 5 years (Table 4). For the years when the sample was large, the best result was in 1984, when 13 of 14 collared animals occupying open upland habitats were seen. The one missed was a young male in a group of 17 that were camouflaged on a broken snow background in the Tomias survey area. In 1986, four of five collared caribou missed by the census were in the same group, 23 animals that were effectively hidden behind a topographic feature. Their signals had been detected in that general area during a reconnaissance radio-tracking flight the previous day, but during the census they could not be located visually.

Census success, the proportion of collared adults seen on surveys, varied among years, but not significantly (Variance Test for homogeneity of the binomial distribution, 1981-1986, $p = .54$). The 5-year average, 43%, can be used together with the annual variation to provide estimates, with confidence limits, of the number of adults in the population (I. Hatter, personal communication). For 1982 and 1984, when all three survey areas were censused, the resulting estimates and 90% limits are 2256 (1846-2902) and 2114 (1729-2719), respectively. Although too imprecise to detect short term trends, those estimates and the data in Table 4 indicate that usually only one-half or less of the Spatsizi population is counted during rut surveys.

Representativeness - A major objective in the fall caribou rut surveys is to obtain data on population composition, particularly the proportion of calves and bulls. Since limiting the surveys to rut concentration areas may result in missing half or more of the Spatsizi population, an important consideration is whether the composition of the animals missed by the surveys was the same as that for those observed. Table 5 compares results for males and two classes of females

The small sample for males suggests that they were somewhat more apt to be on the survey areas at rut time than were either class of females. The only males that failed to appear in the immediate vicinity of a rut survey area were two young animals, aged 3 and 4, in 1983. The distribution during rut was scattered that year, with less than one-third of 28 collared animals on survey areas at survey time. Both missing males were on or near the Tomias survey area in 1984, although the younger one was not in the uplands on the day of the survey.

The most important finding relative to inventory during the Spatsizi studies is that females with calves appear to be less likely than those without to attend the fall rut concentration areas. For the 2 years with adequate calf samples (1984 and 1986, Table 5) only half of the collared females still with calves in the fall were located in the immediate vicinity

Table 5. Distribution of radio-collared caribou during fall rut surveys in Spatsizi Wilderness Park, British Columbia. The data indicate the presence of collared animals in the general vicinity of Caribou Mountain, Tomias Mountain, and Edozadelly Mountain during surveys in five study years. The columns under "visible" indicate occurrence in both the designated areas and in open upland habitats during surveys.

	Occurrence in Rut Survey Areas													
	Females with Calves					Females without Calves					Males			
		Present		Visible			Present		Visible			Present		Visible	
Year	N[a]	No.	(%)	No.	(%)	N[a]	No.	(%)	No.	(%)	N[a]	No.	(%)	No.	(%)
1981	2	0	(0)	0	(0)	5	5	(100)	5	(100)	2	2	(100)	2	(100)
1982	1	0	(0)	0	(0)	2	2	(100)	2	(100)	0	-	-	-	-
983	2	1	(50)	1	(50)	20	10	(50)	8	(40)	4	2	(50)	2	(50)
1984	8	4	(50)	3	(38)	14	12	(86)	9	(64)	4	4	(100)	3	(75)
1986	8	4	(50)	4	(50)	10	10	(100)	10[b]	(100)	1	1	(100)	1[2]	(100)
ALL	21	9	(43)	8	(38)	51	39	(76)	34	(67)	11	9	(82)	8	(73)

[a] Sample sizes, not including females whose fall maternal status was unknown (2 in 1983, 2 in 1986), females whose maternal status and fall location were related to study activities (1 in 1986, see Appendix 3), or animals whose fall locations relative to survey area boundaries were not known (1 female in 1982).

[b] In 1986, one female and one male were contacted, but not seen, in the survey areas; they were believed to have been in survey uplands and are assumed to have been seen, but not recognized, during the survey.

of the rut survey areas, as opposed to 90% of those without (X^2=6.81, df=1, p=.009). That general relationship also holds for the combined results of all 5 years, with fewer than half of the females with calves and more than three-quarters of those without appearing on survey areas (X^2=6.53, df=1, p=.011). In terms of distribution both in the survey areas and in open habitats where observation is possible, females without calves were nearly twice as likely to be counted than were those with calves (1984 and 1986 only, X^2=3.85, df=1, p=.047; all 5 years, X^2=4.77, df=1, P=.028).

There is a biological basis for the observed pattern. That is, the fall distributional differences between successful mothers and other females is probably a manifestation of differential behavior between those two classes (Hatler 1986a). The underlying theme appears to be the animals' strategy for protecting the young from predators. Females are most dispersed in spring, just prior to calving. Throughout summer and fall, those with calves move less and generally remain in smaller groups than do females that are non-parous or have lost calves.

Those movement and grouping patterns hold through the rut period, and probably until weather factors force a return to winter range. Figure 7 shows the summer to early winter changes in distribution between the two classes of females relative to the rut survey areas. Locations listed as "unknown" in Figure 7 are nevertheless known not to have been on or near the survey areas. The tendency for successful mothers to remain dispersed in relatively small, inconspicuous groups may produce continuing benefits throughout the summer and fall. Hatler (1986a) noted that predators are commonly seen in upland habitats with the caribou during fall surveys, therefore avoidance of those areas by some successful mothers could be another part of that strategy.

Even mother-calf pairs that do appear in the survey areas, mostly those from calving locations nearby, tend to remain less attached to the rut concentrations. Following subjective observations that small caribou groups in the fall appear to support proportionately more calves than do larger ones (Hatler 1978, 1980b, 1983a), Ramey (1984) confirmed it in a detailed analysis of Spatsizi census data from 1976-1983, concluding that "...the proportion of calves decreases exponentially as the group size increases."

The significantly different range use tendencies between the two classes of females among the collared sample, as shown above, suggests that fall counts on the survey areas may be biased against females with calves. To further assess that possibility, Table 6 compares fall calf ratios among the collared sample with those obtained in the general surveys. In 4 of 5 years, the collared animals showed a higher calves:100 females ratio than did the

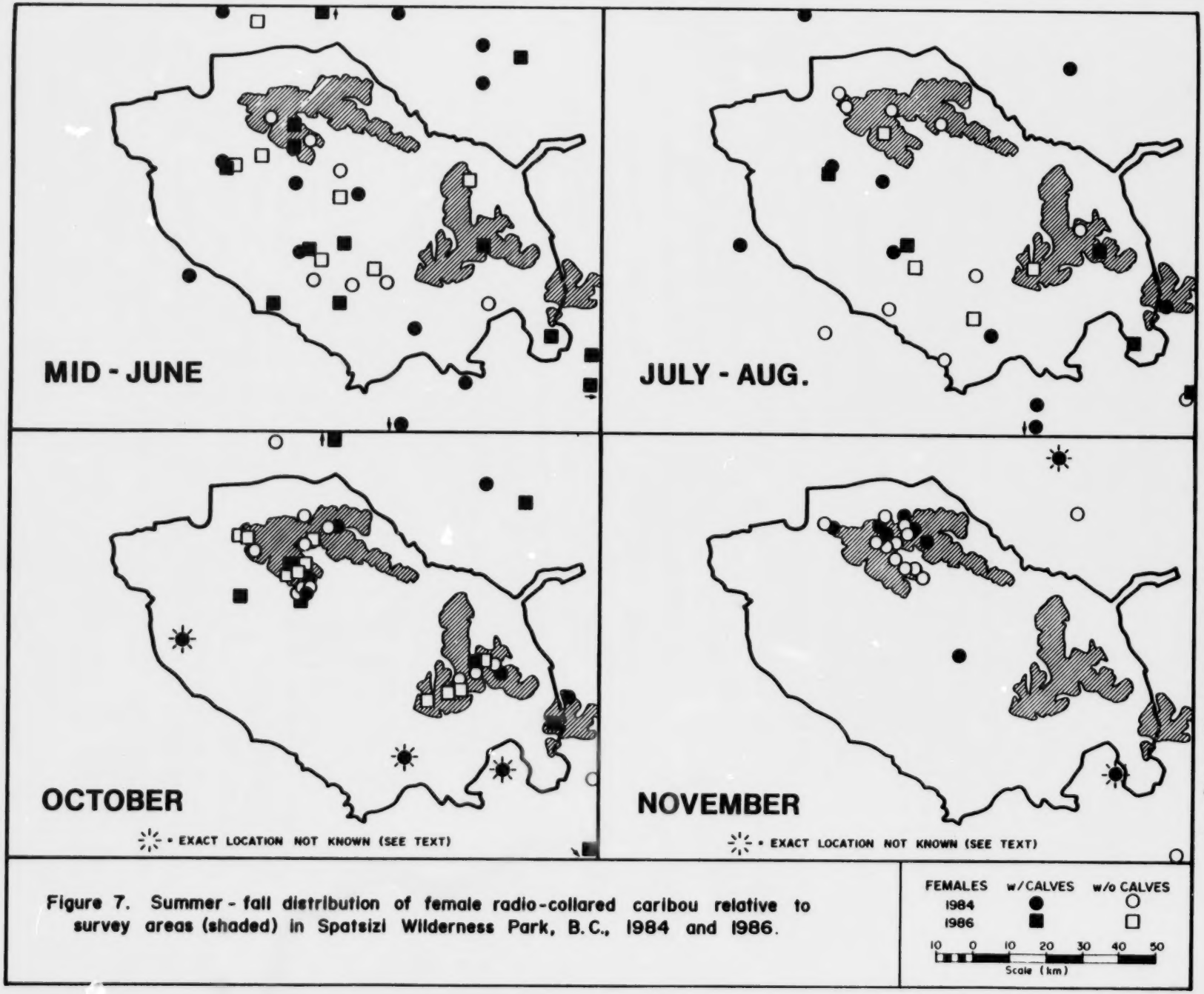


Figure 7. Summer - fall distribution of female radio-collared caribou relative to survey areas (shaded) in Spatsizi Wilderness Park, B.C., 1984 and 1986.

Table 6. Comparative fall recruitment data between radio-collared and visual survey samples of caribou in the Spatsizi Wilderness Park area, British Columbia, 1981-1986. Recruitment is expressed as calves:100 females; also shown are chi-square (X^2) comparisons of the two kinds of sample results.

	Collared Sample		Survey Sample				
Years	N	Calves:100F	N	Calves:100F	X^2	df	p
1981	7	28.6	305	11.5	1.91	1	.167
1982	4	25.0	722	13.9	0.41	1	.521
1983	20	10.0	274	23.7	2.00	1	.158
1984	20	45.0	431	26.7	3.22	1	.073
1986	18	44.4	483	24.4	3.69	1	.055
1984 + 1986	38	44.7	914	25.5	6.97	1	.008
All but 1983	49	40.8	1914	19.0	14.55	1	<.001

animals classified in the corresponding visual surveys. Thus, the results for those 4 years are consistent with expectations based on the differential female distribution pattern discussed above. Within year comparisons for 1981 and 1982 do not produce statistical significance, because the collared sample was small in those years. However, the probabilities of the 1984 and 1986 results, when the collared sample was 18-20 and had an adequate representation of successful mothers, were less than .10, and the lumped results for those 2 years, and for the 4 consistent years, are significant beyond the .01 level of probability.

Since it appears to provide some contradictory evidence, the result for 1983 requires discussion. Among the 3 years when the collared sample was largest, 1983 differed from the others in that the fall survey was conducted on only two of the three survey areas. Tomias Mountain was not surveyed in that year and, as shown in Figure 8, during the five occasions in the last decade when all three areas were surveyed, Tomias Mountain results have always constituted more than half the total sample and have always been a negative influence on the calf percentage. Indeed, there appears to be an inverse relationship between calf percentage and the proportion of the total sample gathered at Tomias (Spearman Rank Correlation Coefficient = -.975, N=5, $p<.05$). Statistical analysis also indicates that the differences in calf percentage between Tomias and the other two survey areas occurred at lower than the .10 probability level in 3 of those years, and in the lumped, 5-year sample:

	X^2	df	p
1977	20.42	1	<.001
1980	1.59	1	.208
1982	1.59	1	.207
1984	3.59	1	.058
1986	9.96	1	.002
ALL	35.53	1	<.001

Thus, there is evidence that the 1983 survey result was biased upward, and therefore that its difference from the collared sample, if any, was even less significant than indicated in Table 6.

Some of the other comparisons in Table 6 may also be influenced by biased survey composition data. That bias results from the necessity to compute calves:100 females only with data from groups that were completely classified. The most common reason for failing to classify a group is that it is too large, thus there is a tendency to bias the sample total to the

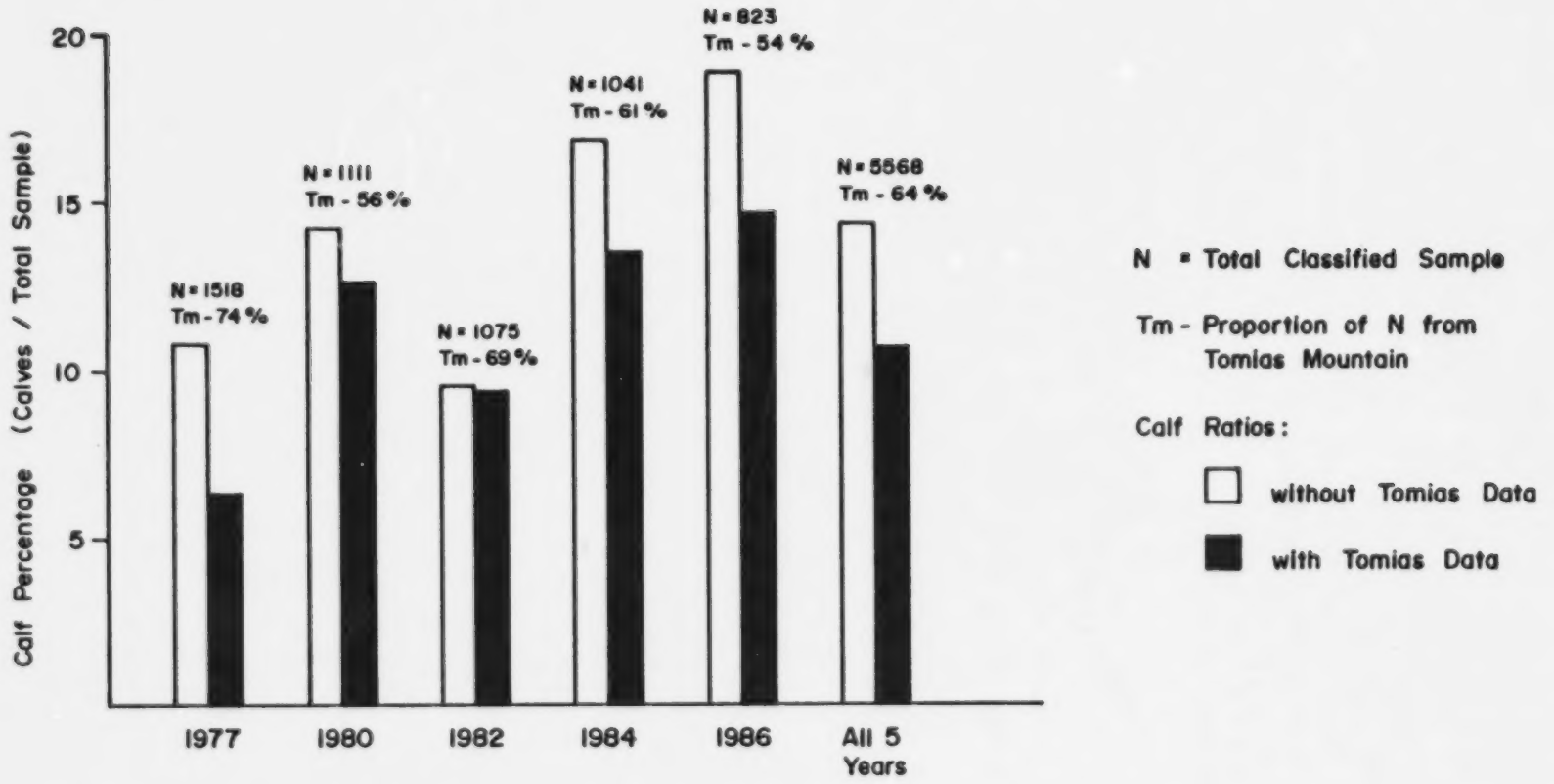


Figure 8. Impact of data from Tomias Mountain on Spatsizi Park caribou calf percentages, 1977 - 1986.

smallest groups, which have the highest proportion of calves (see above). For example, during the 1984 survey (Jones 1984b), observers found 108 calves among 659 animals (16.4%) in groups classified completely, and 31 calves among 386 (8.0%) in groups for which classification of all adults could not be accomplished. Despite the difference between those results (X^2=14.74, df=1, p<.001), data expressed as calves:100 females (Jones 1984b; Table 6 this report) can be drawn only from the former.

In summary, for an inventory system to succeed in accurately portraying the composition of a caribou population, it must either be timed to catch the animals when all classes are in the same place, or must be designed to account for differential range use and group affinities between classes. The observations summarized above, the only direct evidence available on the subject, suggest that the rut surveys in Spatsizi Provincial Park do neither.

Flight Considerations - In the Spatsizi area we have used fixed-wing aircraft for pre-survey reconnaissance and helicopters, mostly Bell 206's, for surveys. A helicopter is essential to sex animals by observation of genitalia, and is preferred when group sizes are large and animals are in rugged terrain. In some situations, surveys from high performance fixed-wing aircraft may produce satisfactory data on numbers and on population composition at Level 1 and 2 standards of classification (Appendix 1).

Rut Survey Timing - If there is an optimum time for conducting a census, it should be predictable by reference to some consistent and regular progression of observable events in the life history of the animals. A series of reconnaissance surveys in the early 1980's attempted to identify the optimum timing for fall rut surveys by monitoring caribou occurrence in selected uplands between late September and mid-October. The assumption was that the combination of animal movements and grouping behavior during pre-rut would eventually bring a maximal number of animals together into a minimal area. On the Kawdy Plateau, northwest of Spatsizi, van Drimmelen (1983) looked for..."the peak aggregation (and therefore optimum inventory time)...", but it was not clear how that peak could be recognized, except in retrospect. Likewise, Jones (1982b) in the Spatsizi - Tatlatui Parks area, and Sather (1983a,b) in Spatsizi and Mount Edziza Parks, documented differences in counts on survey uplands over the pre-rut period, but did not demonstrate any certain patterns that might help to identify the best survey timing.

The biological basis for expecting a regular, progressive increase in aggregation during the fall is unclear. Most studies have confirmed that mean group sizes are usually larger at rut time than in other seasons, but I am

aware of none that have documented systematic increases in group size or decreases in local density within the general rut period (see Hatler 1986a). Perhaps the most intensive study of rutting behavior among woodland caribou is that of Bergerud (1973) on the Mount Albert Plateau, Quebec. In that area, which he has elsewhere noted is similar to the Spatsizi Plateau (Bergerud 1978a), "...breeding activity appeared to be restricted to an open plateau of 5.5 square miles although the animals were free to move from the plateau to the forest below the mountain, and frequently did so." The study lasted from 12 September to 29 October, with the peak of the rut judged to be about 7 October. During that study period the author noted that at least 166 different caribou visited the mountain, but that "...usually less than one-third were present on any one day."

Observing rutting barren ground caribou, Lent (1965) noted the dynamic nature of individual groups; his observations were made difficult by the animals constantly moving, en route to winter range. Henshaw (1970) contended that the movements and interactions of migrating caribou have a functional significance to breeding.

If caribou in northern British Columbia also rut during fall migration, rather than migrating in fall to rut, there are some important implications for inventory. The latter pattern is the assumption upon which the fall inventory strategy is built. Bergerud and Butler (1978) felt that the rutting ranges may be the most important habitats in the animals' annual cycle, drawing the animals in "...from very long distances." However, if the general destination of fall movements is actually the winter range rather than the rut areas, then occurrence on those rut areas may be more fortuitous than traditional, depending on factors quite unrelated to the rutting drive. Among those factors are late summer distribution, itself possibly reflecting effects of other factors such as temperature, precipitation, and disturbance by predators or insects.

Weather factors during the fall may also influence pre-rut and rut distributions. B. Henderson (pers. comm.) believed that the relative absence of caribou in Tatlatui Park uplands in fall 1985 was due to a series of exceedingly windy days. Bergerud and Butler (1978) noted that "snow is the sign stimulus that releases migration" in caribou studied elsewhere, and speculated that the observed rapid departure of caribou from Tomias Mountain in 1977 was a response to snow. Early snowfalls may therefore have the potential for moving animals on and off rutting areas earlier in some years, and thereby undermining a local survey strategy focusing on rut timing alone.

Effect of Group Dynamics - Budget and time limitations during the Spatsizi census evaluations did not allow many replicate observations of collared animals within surveys except in 1981, when the survey and evaluation were carried out simultaneously from a helicopter. On that occasion, both negative and positive potential biases on survey results were identified. The negative biases were mostly due to animals occurring outside the survey area, as described in Section 3.3.2. The potential positive biases arose as a result of a) group movements and instability, and b) the necessity to backtrack over some areas. The specific observations involved, obtained on the Caribou Mountain survey area over the period 9-12 October, are summarized below (from Hatler 1983a).

The 1981 survey was terminated early on 9 October because of deteriorating weather, and was interrupted once on the 10th because of temporary low cloud. One group, recognizable by the presence of a collared bull, was seen at three different locations several kilometers apart, once on the 9th and twice on the 10th. That group consisted of 13, 14, and 16 animals on the three contacts, and those sightings would likely have been recorded as three separate groups had the collared animal not been present.

Another group of 43, counted from the ground, was seen less than an hour later as two separate groups, 33 plus 15 = 48, going in opposite directions. Again, the presence of collared animals, two in the original group with one going to each of the subsequent groups, made correct interpretation possible. Two days later those two collared animals were back together in a group of about 40. To summarize, the 1981 count would have been inflated by 30-45 animals, raising the total and duplicating the composition sample by almost 20%, without the collared animals to identify specific groups. Rutting groups of caribou appear to be so mobile and dynamic that there is a high risk of duplication in surveys not completed over a short time or that, either by design or faulty navigation, involve a return to an area previously covered.

Most biases resulting from unstable and unpredictable grouping behavior are probably negative. On Mount Albert, Quebec, since no more than one-third of the animals were present on the upland rutting areas on any one day (Bergerud 1973), no more than one-third could have been tallied on an aerial survey over those uplands in any one day. Although the reconnaissance surveys in northern British Columbia in the early 1980's did not confirm the existence of a predictable, optimum survey time during the rut, they nevertheless provided some important insights. For example, van Drimmelen (1983) counted 616 caribou during a "routine reconnaissance flight" over the Kawdy Plateau on

1 October 1983, but could locate only 415 on the official survey 9 days later, "...despite a four-fold increase in search intensity...(and) ideal observation conditions..." After Spatsizi surveys the following year, Jones (1984b) described observations that served to "...reinforce earlier impressions that caribou groups are dynamic, and group sizes can fluctuate over short periods." AIM (1982) also highlighted day-to-day variations in fall counts on uplands in the Lawyers Pass area, southeast of Spatsizi Park. Whether involving shifts between rut areas, or occasional movements by some animals into cover where they are not readily seen, the above results provide further evidence that surveys designed to assess local caribou numbers or population composition by single counts on fall rut areas have a high risk of missing a significant proportion of the animals.

Minimum Counts Versus Sampling - Most of the caribou surveys that have been conducted in British Columbia have had an objective of "total count" within the area of coverage. The evaluation studies reported here have shown that such counts in the three survey areas at Spatsizi are minimum counts of the local population, failing to tally 50-70% of marked caribou in any given year and probably missing a similar proportion of unmarked animals. For some objectives, such minimum counts may provide adequate information. Harvest rates set on the basis of minimum numbers are more demonstrably protective of the resource than are those based on extrapolations from samples, and Jones (1985a) has demonstrated a rational approach to using the Spatsizi data to justify and maintain conservative harvests in Spatsizi Park. Although such conservatism may be appropriate in parks, similar use of minimum count data in other areas may short-change the consumptive user. That is particularly true if the count includes a negatively biased estimate of recruitment. A potential detrimental side effect of "under-harvesting" is reduction of the apparent economic value of a population, thereby deflating arguments against competing land uses.

In short, some harvest objectives can be met without knowledge of count accuracy or precision. For objectives that relate or refer specifically to population changes, minimum counts are not adequate. Examples of such objectives are the proposed population increase goals specified in the provincial caribou management plan (BCFW 1979), and all research or management directed to population changes from predation, predator control, or habitat factors. To provide population estimates with measurable limits of accuracy and precision, a sampling system is required.

3.4.3 Conclusions: The Utility of Rut Surveys

Of the three annual times that seem the most suitable for census of caribou in the Spatsizi area (Table 3), only the census during the fall rut period has been used regularly and evaluated. Although Bergerud and Butler (1978) thought that October counts in Spatsizi Park "...included nearly all of the population...", our evaluation results over 5 years suggested that such counts usually miss more than half the population. The fall counts were demonstrably biased against young-of-the-year, and possibly also against bulls, and those are the two classes of primary interest in the surveys. During the rut, many groups are too large to classify completely, resulting in a conflicting bias in recruitment data, since the smallest groups are those with the most calves. The rut also appears to be a time when groups are particularly mobile and lacking in cohesion, so that it seems impossible to predict even their day-to-day locations. Fall surveys therefore appear to be of limited usefulness for determining caribou population status in Spatsizi Park, and probably in other areas of northern British Columbia.

4. CARIBOU POPULATION DATA IN SPATSIZI PARK: A HISTORY AND ASSESSMENT

4.1 Introduction and Rationale

Foregoing sections have presented results of inventory development and evaluation studies in the Spatsizi area, mostly in reference to a sample of radio-collared animals. The purpose here is to apply those results, and new information on local life history (Hatler 1986a), in considering the history, reliability, and significance of all known Spatsizi caribou population data. Although not intended specifically as a critique, the overall flavor of this offering is nevertheless critical in seeking to distinguish between what we know about the animals (hard data) and what we think we know (interpretation of data). As outlined earlier, Spatsizi data have been widely cited and interpreted in recent theoretical literature on caribou population dynamics. Thus, it seems particularly important to consider, in detail, the validity or limitations of those data.

The Spatsizi situation, as assessed in this and the previous section, will serve as an example for reference in consideration of inventory evaluations, needs, and prospects elsewhere in the province. It seems appropriate as an inventory example not only because of the recent pertinent research there, but also because it appears to have the longest and most regular record of caribou population information in the province.

4.2 History: 1905-1959

The upper Stikine River drainage has long been known to support a significant caribou population, but all assessments of numbers and status in the initial deliberations of provincial wildlife administration were apparently subjective, and few were specific to that area. In reports of the Provincial Warden (BCPW 1905-1935) and the Game Commission (BCGC 1936-1956) to the Legislative Assembly, most early references to caribou in northwestern British Columbia were for "the Cassiar District", which included the Atlin-Teslin area and drainages of the Taku and Dease Rivers as well as that of the Stikine. In the first report (BCPW 1905), caribou were described as "especially plentiful in Cassiar this year," and good reports also pertained in following years with "...bands of 15 to 20 being constantly in view...(and)...one band of 150 head...reported" (BCPW 1908), "...a very large herd, numbering between 300 and 400 head..." (BCPW 1909), "everybody reported seeing numbers..." (BCPW 1910), and "...one hunting party... (saw)...some 1200 head in a few days hunting" (BCPW 1914). Almost all of the wildlife status information for northern areas of the province at that time was based on

verbal reports from guides and hunters. Unfortunately, the locations of sightings were rarely given.

A severe winter was believed to have resulted in a "considerable" loss of moose and caribou in northern British Columbia (BCPW 1918), and the subsequent report noted that "Caribou are very scarce and with the exception of the section in the vicinity of the head of the Stikine River, very few are to be found" (BCPW 1919). That is the only reference specific to the present Spatsizi Park area in the BCPW reports through 1935. Despite the apparent losses in at least some areas during the 1917-1918 winter, reports throughout the 1920's and early 1930's were of stable or increasing caribou numbers in the northern half of the province. Neither those reports, nor that indicating large losses to a later hard winter and increasing predators (BCPW 1935), provided any hard data or citations of any particular authorities.

In subsequent reports in the provincial government series (BCGC 1936-1956), the only references to caribou in the study area were for the years 1949-1953, in each of which it was noted that the animals in the Coldfish Lake area were doing well. Those reports apparently came from communications with T.A. Walker, the guide-outfitter operating there at that time. The first series of observations that included actual counts of caribou in the Spatsizi area were those extracted by Walker (1978) from his personal journals for the years 1948-1959. Appendix 4 summarizes those observations, other historic reports considered significant by Bergerud (1978a), and all subsequent official observations and surveys through 1985. Following sections consider those data in terms of whether they can reliably serve to delineate trends in either population composition, with emphasis on recruitment, or numbers.

4.3 Data on Recruitment

The term "recruitment" applies to various measures of calf abundance. For consistency with usage in most of the important theoretical papers cited earlier, and except where noted otherwise, its use here refers to the percentage of calves in relation to total numbers. Considering data through 1977, Bergerud (1978a: Table 10) distinguished three different periods of calf abundance in the Spatsizi area. During the first, shown as occurring before wolf control, he calculated a moderately low average of 11% calves for data from Walker (1978) over the years 1951-1957. The period after wolf control in the area is represented by the observations of Hartman (1962) and Mundy (1963), their combined sample of less than 200 animals including almost 30% calves. The third period, with calf ratios no higher than 7%, is calculated from several observations between 1973 and 1977. The implied comparison

assumes that all of the indicated observers were uniformly interested in recording caribou calf ratios, and that any two samples are comparable, regardless of season, location, or relative size. Assessments of those assumptions follow:

4.3.1 Survey and Observation Objectives

All of the Spatsizi caribou data prior to fall 1976 were collected only incidentally to other work (Appendix 4). Mountain sheep were the primary focus both for the summer reconnaissance and early fall hunting trips when Walker (1978) recorded most of his data, and on the aerial reconnaissance surveys of Hartman (1962), Mundy (1963), and Harper (1972). In footnotes to his journal summaries, Walker (1978) emphasized that he did not attach any particular significance to calf ratios given the general abundance of caribou in the area, and that he did not systematically record them. Surveys focusing on caribou and paying particular attention to the incidence of calves commenced in 1976 (Appendix 4).

4.3.2 Sample Size Effects

Although Walker (1978) reportedly counted a total of 1513 caribou in 1951-57, he classified only 354 (23%) of them to the adult/calf level. Because caribou groups may differ considerably in composition, with some sex segregation in spring and early summer (Fuller and Keith 1981; Edmonds and Bloomfield 1984; Hatler 1986a), a segregation of many females with calves from other caribou classes in summer and fall (Section 3.4.2), and a tendency for females with calves to remain in smaller groups through at least the rut period (Section 3.4.2; Ramey 1984), the probability that the composition of a small local sample will accurately reflect that of the total population is slight. If the Spatsizi population numbered at least 1500 animals in the 1950's and 1960's, as has been the case since a reported (Bergerud 1978a) early 1970's decline, then Walker's (1978) composition data were for an average of no more than 3% of the population annually, and data from Hartman (1962) and Mundy (1963) were no more than 2.5%.

Relatively small differences in sample size may affect the apparent calf percentage, as illustrated by a comparison of the early 1950's data from Walker (1978) both as listed in Appendix 4 and in Bergerud (1978a). Of the 354 animals classified to at least adult-young categories in 1951-57, 79 (22%) were calves. By selection criteria not explained, Bergerud (1978a) rejected 156 of the animals in Walker's sample, an average of only about 1% of the conservatively estimated population per year, and that resulted in reducing the calf ratio by one-half, to 11%.

4.3.3 Duplication

A special problem with the series of data from Walker (1978) is that because his totals accrued in relatively local areas over a period of months in most years, the extent to which he may have counted the same individuals more than once in a particular year cannot be determined. Repeated counts of the same maternal or bachelor groups have the potential for inflating or deflating apparent calf ratios, particularly in the case of small overall samples of classified animals. For example, a sample consisting of a group of 3 adults mistakenly counted three times plus a group of 3 adults and 3 young seen once yields a calf percentage of 3/15=20%, whereas the actual percentage of animals present is 3/9=33%. The data presented by Bergerud et al. (1984) for calf ratios at Fire Flats in summer 1977 were also based on cumulative samples where considerable duplication was likely.

4.3.4 Effects of Survey Location

Female caribou in the Spatsizi area disperse widely throughout the general park area for calving, and remain scattered, mostly at high elevation, throughout the summer. Among the areas used by maternal bands of caribou are the ridges and steep slopes also occupied by mountain sheep and goats in the Eaglenest and Klappan Ranges. Since the activities of Walker (1978), Hartman (1962), and Mundy (1963) largely focused on sheep, it is not surprising that many of their observations were of such maternal bands. Of the 79 calves reported by Walker (1978), 50 (63%) were in the Eaglenest Range and 22 (28%) were in alpine habitats being hunted for sheep and goats in the Dawson and Upper Ross River areas. Only 7 (9%) were seen on or near the alpine plateaus where fall caribou surveys are presently carried out. Of 117 caribou observed by Hartman (1962), 89 (76%) were in the Eaglenest Range and only 19 (16%) were on a currently used survey area (Caribou Mountain). The activities of Mundy (1963) centered on Kinaskan Lake, southwest of Spatsizi. Of the 54 caribou among his observations, perhaps most with affinities to the Spatsizi population, none were in areas normally surveyed and only 5 were within park boundaries. In summary, most of the important historic data on recruitment were collected in habitats that favor maternal groups, particularly in comparison with the habitats where most data were collected subsequently.

4.3.5 Effects of Survey Timing

The subject of timing is not strictly separable from that of location, since the local distribution of animals is seasonal. Thus, most of the historic (pre-1976) data discussed in 4.3.4 were gathered not only in habitats favored by maternal groups, but also in summer, presumably before all of the year's calf mortality had occurred.

Figure 9 portrays calf percentages for all Spatsizi Park surveys or observations, since 1976, that involved a Level 1 or better composition sample of at least 100 caribou (data from Appendix 4). There are only two summer records for the past decade, one low and one high. The low summer calf ratio involved an incidental, July 1976 observation of only 6 calves among 366 caribou (1.6%) at Fire Flats, the area of focus for calf mortality studies in summer 1977 (Bergerud and Butler 1978; Bergerud et al. 1984). That area, at the park's western boundary, is now known to be an early summer range used primarily by males, non-parous females, and females that have lost calves, therefore a high calf ratio would not be expected (Hatler 1986a). Despite the fact that the 1976 Fire Flats observation involved a sample size more than three times larger than any single sample before 1976, it was clearly not representative of the population since even the fall count of that same cohort was substantially higher (Figure 9).

The high summer calf percentage shown in Figure 9, 24% of 171 animals, was obtained during mountain goat surveys in July 1984 (Hatler and Hazelwood 1984), thus objectives, habitats, and timing were comparable to those for surveys during the alleged high recruitment era (Hartman 1962 and Mundy 1963, as cited in Bergerud 1978a), and the results are similar. Incidental observations during summer mountain goat surveys in other northern British Columbia parks in recent years have also yielded relatively high caribou calf percentages: Tatlatui Park - 26% of 74 animals (Jones et al. 1981); Tatlatui and southern Spatsizi Park - 29% of 226 animals (Hatler and Hazelwood 1985).

Another important feature of the data depicted in Figure 9 is that winter composition samples have yielded significantly higher proportions of calves than were obtained for the same cohorts in the previous fall counts (1978-79: $X^2=2.78$, df=1, p=.096; 1980-81: $X^2=9.09$, df=1, p=.003; 1981-82: $X^2=13.65$, df=1, p<.001). That result may be due mostly to the post-rut return of outlying maternal groups to areas occupied by other classes, although the winter calf percentages could be exaggerated by a disproportionate movement of bulls away from the survey areas (Hatler 1986a).

4.3.6 Conclusions: Recruitment Data

Caribou tend to occur in groups that are often segregated in regard to particular classes, and distributed such that representative samples are difficult to obtain. Due to natural attrition of calf cohorts over time, it can generally be expected that summer calf ratios will be higher than those later on. Small local samples, or cumulative duplications thereof, are therefore not reliable indicators of overall population composition, and comparisons between seasons do not appear to be valid.

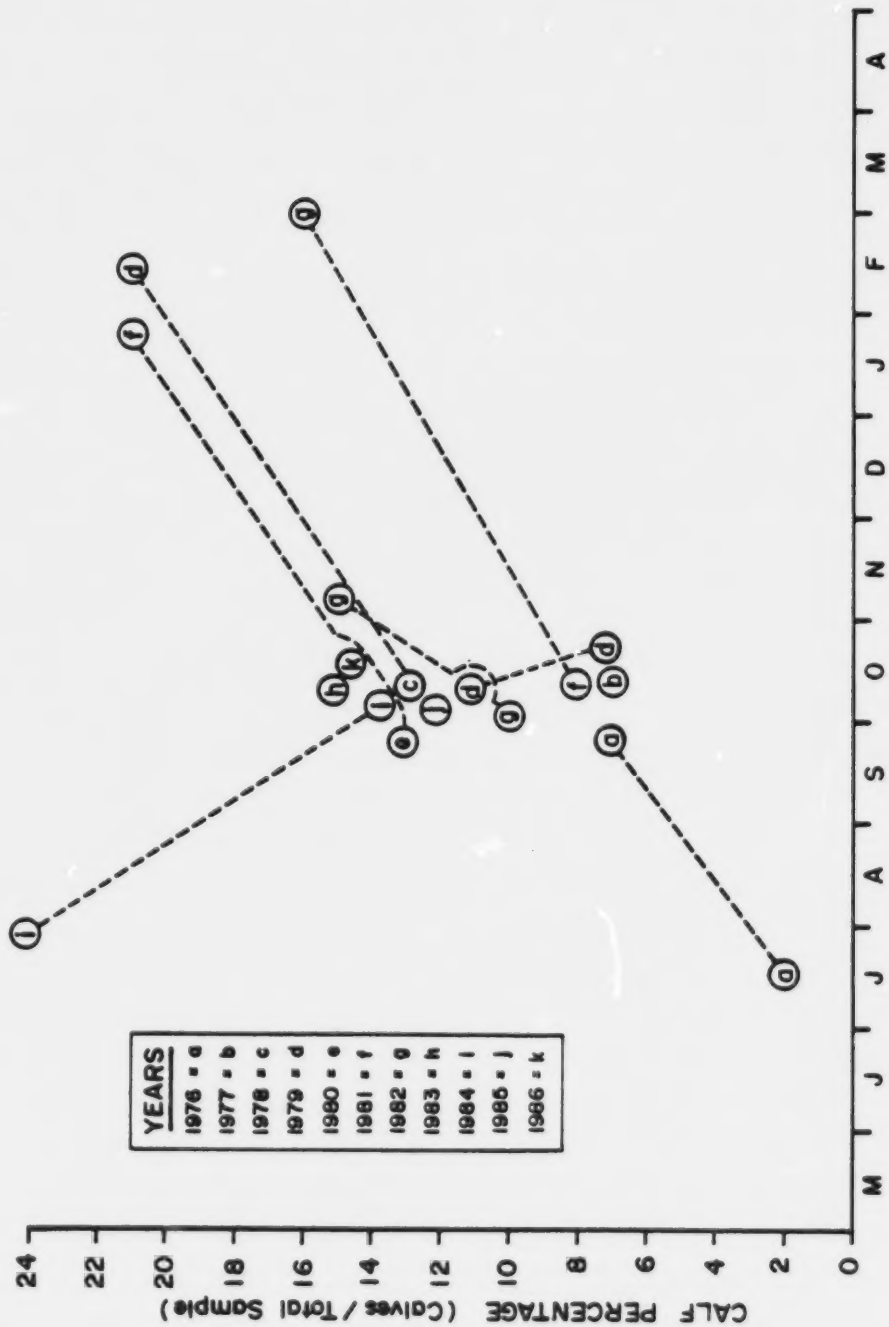


Figure 9. Caribou calf percentages recorded on surveys in Spatsizi Wilderness Park, B.C., 1977-1985. The data points, all representing unduplicated composition samples of at least 100 animals, are depicted by circles indicating the year of observation. Dotted lines connect observations involving the same cohort of calves.

4.4 Data on Numbers

During the first half of this century, consideration of caribou population trends in northern British Columbia was completely subjective, based on guide and hunter reports (Section 4.2). For the Spatsizi area, there were occasional counts between the late 1940's and the mid-1970's, but all were either "local", i.e., restricted to a relatively small area, or "partial", i.e., somewhat more extensive but still not covering all occupied caribou range within any short time period (Appendix 4). Such data, therefore, were all that Bergerud (1978a) had to determine past trends and status of what he called "the Spatsizi Park Herd". His conclusion that the herd was in decline, having dropped by 40-50% from a high in the early 1970's, was supported by comparisons of partial counts between 1973 and 1977 in two different areas of the park, and in two different seasons.

One comparison was for the northern portion of the park, based on results of a B.C. Land Inventory flight (Luckhurst 1973), and an experimental transect survey (attributed to T. Sinclair in Bergerud 1978a). Both surveys were in winter. The other comparison is for July observations at Fire Flats, the 1973 high of 600-650 animals coming as personal communication recollections from Guide Outfitter R. Collingwood and recreationist J. Lau (Appendix 4), and the lows from observations by government personnel and Bergerud in subsequent years. Following paragraphs consider some of the factors that might have affected either results or interpretations at the times and locations indicated.

4.4.1 Differing Survey Objectives

As described by Luckhurst (1973), the purpose of his survey "...was to obtain a general picture of big game distribution in relation to landforms, snow depths, and vegetation patterns." His area of reference over a 3-week period, 22 March - 10 April 1973, included all of the British Columbia portions of five mapsheets (1:250 000 scale, National Topographic Series), a total of 56 000 km^2. For the mapsheet of interest here (104H, Spatsizi), he flew east-west transects 5 km apart in the northern (Stikine Valley) portion, which includes important forested caribou winter range (Hatler 1986a). However, in the mountains that constitute the majority of the area to the south, the flight pattern was "...along contours at selected elevations in an attempt to get the best picture of distribution and to locate major concentrations of ungulates." In short, he used his local experience to maximize his chances for locating animals and identifying important habitats. Although his survey clearly did not seek caribou population data, his total

count of 623 animals was the highest short-term total for the area within present park boundaries until 1976, when intensive helicopter surveys on rutting areas began.

The March 1977 Sinclair flights were the last in a series of four surveys in the area, the first three having been completed in March, May, and September of 1976. Because those surveys included flight lines and intervals similar to those used by Luckhurst in the northern portions of the park, Bergerud felt justified in comparing the two surveys for that portion of the area. I was involved in the Sinclair surveys, and recall that initially there was some hope that the systematic, calibrated transect technique being used would produce a Spatsizi caribou population estimate, with confidence limits. Unfortunately, the terrain and cover in Spatsizi were apparently not well suited for a technique that had been developed on the savannahs of Africa, and no population estimates were obtained. A publication resulting from that work (Boonstra and Sinclair 1984) documents seasonal distribution of both caribou and moose in the study area, but does not mention the numbers tallied for either species.

The March comparisons in the northern Spatsizi area, therefore, were based on one survey designed to document distribution and habitat use, but which opportunistically also found numbers, and another originally planned to document numbers, but which settled for a consideration of distribution and habitat use.

The objectives of the pertinent Fire Flats observations are more simply described. Those in 1973, and those by government personnel (Carswell 1975; Hatler 1976a), were incidental during flights in the area for other purposes. The counts in summer 1977 were made by researchers in the process of gathering data on local population composition (Bergerud and Butler 1973).

As will be shown in Section 4.4.5, extensive surveys designed to assess population trends have been largely unsuccessful. It seems unlikely that local counts not intended for that purpose would do better.

4.4.2 Winter Distribution Effects

Bergerud's (1978a) deliberations were made without documented knowledge of seasonal range affinities and population boundaries of the various groups of caribou in the Spatsizi area. He assumed that his "Caribou Mountain Herd", which spent summer and fall in the northwestern portion of the park, consistently wintered in that area, separate from other such groups. Radio-tracking studies have shown that not to be the case. Animals from widely separate summer areas may all be found in the lower Stikine Valley winter range, especially in late winter (Hatler 1986a). Winter distribution appears

to be determined largely by climatic conditions, probably mostly characteristics of the snow cover; also, there are both geographical and elevational responses to consider. For example, numbers of animals from the Finlay River drainage are known to remain there in some winters, but at least some move north to Stikine River habitats for all or portions of other winters. Meanwhile, animals whose winter range affinities are primarily to lower Stikine forests may nevertheless spend all or portions of some winters well north of the Stikine River, in areas not covered by either Luckhurst (1973) or Boonstra and Sinclair (1984).

The underlying assumption of the 1973 vs. 1977 winter surveys comparison is that a particular block of winter habitat will consistently harbor, year after year, the same proportion of the total population. Judging from the telemetry results, there is no biological basis for such an assumption. Further, even if the same number were always present in the area of reference for that comparison, differential elevational distribution of animals could yield widely varying counts. During the inventory development studies (Section 3.4.1), most of the local animals were in alpine areas and were therefore maximally visible for most of the 1980-81 winter, many were in such areas for part of the 1981-82 winter, but there was no significant occurrence above timberline in either of the two following winters. Statements and maps in the pertinent reports indicate that local elevation distribution was very different in the comparison years. Luckhurst (1973) counted most of his animals above treeline, while Boonstra and Sinclair (1984) found them mostly in the subalpine zone, or below, in March of both 1976 and 1977.

4.4.3 Effects of Sample Size (Partial Counts)

Although the 1973 vs. 1977 comparisons were total counts of animals seen in specified areas, they were nevertheless samples in the sense that each comprised only a portion of the total population. The number attributed to the reference area during the March 1977 survey was 313, which was only 19% of the animals later counted on Spatsizi Park rutting ranges in October that year and just 13% of the rut survey total in the overall area from which the March sample might have been drawn. Although the March 1977 count within Spatsizi Park boundaries was at least 41% higher than any other that has been attained there in the records through 1986 (Appendix 4), it was interpreted to be 40% lower than the number existing in 1973. By implication, that number would have been as high as 2780, considering only the fall 1977 count in Spatsizi Park, and 4115 if results from adjacent ranges in Tatlatui Park and the upper Finlay River drainage are also included. Given those numbers, from 2100 to 3500 animals were either absent or missed during Luckhurst's (1973) coverage

of the 104H (Spatsizi) mapsheet area.

On the basis of summer estimates and counts at Fire Flats, Bergerud (1978a) also postulated a 1973 to 1977 decline of about 40% for caribou in the Tomias Mountain group (Upper Stikine Herd; Hatler 1986a). Although the movements of radio-collared animals have confirmed the link between Fire Flats and the Tomias area, the animals at the Flats in early summer constitute only a portion of those later found at Tomias and other rutting areas in the Upper Stikine summer range. In summer 1977, that proportion was, at most, 20% (maximum of 236 animals at Fire Flats on 29 July vs. 1154 at Tomias on 8 October; Bergerud 1978a).

Because the composition of the Fire Flats assemblage is not representative of the rest of the herd (Section 4.3.5), it is unlikely that numbers there will occur as a consistent proportion of the total. We still know too little about the nature of the Fire Flats occurrence to interpret differences in counts there confidently, but a variety of explanations other than overall population changes are possible. For example, use of that area may differ from year to year, depending upon characteristics of the previous winter. The high count in 1973 may have been abnormal, resulting from an unusual distribution in late winter, or may have been forced by unusual spring conditions in that year. Since the Fire Flats group is made up mostly of males, non-parous females, and unsuccessful mothers, the number present could also reflect an unusual influx of one or more of those classes. For example, excellent survival of calves in two successive years might greatly increase the local number of yearlings and 2-year olds (both sexes), or very poor local calf survival might increase the number of unsuccessful mothers in the area. Finally, the local high count in 1973 might have been the result of local human development effects. As reported by Haber (1979), the peak of over 600 animals at Fire Flats in July 1973 was accompanied by a decrease of more than 200 animals in similar habitat along the upper Skeena River, just 10-15 km to the south, as compared to July 1972. He cited R. Collingwood, who was also Bergerud's (1978a) source, as believing that there had been a local population shift, triggered by "...disturbance associated with construction of the BCR grade..." (British Columbia Railway) in the Skeena area.

4.4.4 Effects of Survey Timing

The survey by Luckhurst (1973) was no earlier than 22 March, whereas that in 1977 by Boonstra and Sinclair (1984) was on 1-3 March. Given the tendency for animals to move upslope to alpine areas in late winter of some years (Edmonds and Bloomfield 1984; Hatler 1986a), a count on 22 March or later could be substantially higher than that on 3 March even in the same

winter. At Fire Flats, counts may vary daily because, as on the rut concentration areas, groups are dynamic, not static. Bergerud (1978a) noted that during continuous observations there between 15 May and 15 July 1977, a count of 236 on 29 June was the only daily total over 200. One-time, incidental counts in the area, therefore, may or may not occur on peak days.

4.4.5 Rut Counts, 1976-1986

Previous paragraphs have described and assessed attempts to interpret population data that were clearly fragmentary. In 1976, a survey system designed to produce consistent data from year to year was introduced. As described earlier, it involved a complete count of animals on identifiable, upland concentration areas during the rut. It was initially assumed that most of the animals attended those areas in October, and that the combination of open habitats, apparently predictable distribution, and concentration of animals would produce the most efficient, comparable, and cost effective survey possible. Studies of radio-collared animals have subsequently shown that the underlying assumption is not supportable, and that population composition information based on rut-count samples is biased (Section 3.4.2). The present discussion considers whether the fall counts may nevertheless be useful in indicating long- or short-term population trends.

Figure 10 depicts all satisfactory rut survey counts for each of the three Spatsizi survey areas, and for the sum of the three areas during those years when all were surveyed. Jones (1985a) concluded that the count results alone "...could not provide a precise population index..." and looked to demographic data for corroborative evidence. His resulting scenario for population trend during the decade in question is as follows:

a) Decline between 1976 and 1978, essentially a continuation of the pattern postulated by Bergerud (1978a) and Bergerud and Butler (1978), resulting largely from predation.

b) Stabilization from 1979-1985, resulting from improved recruitment and sex ratio, but with predation continued at a level to prevent substantial increase.

He acknowledged that the scenario is debatable, but that it is consistent with available data.

The purpose of the following discussion is to consider the annual count results in relation to what observers thought was actually happening. For present purposes, I have accepted the hypothesis of decline through 1979 and stability for 1980 and 1981. However, I consider it likely that the most significant decline that has occurred in at least the past decade was during

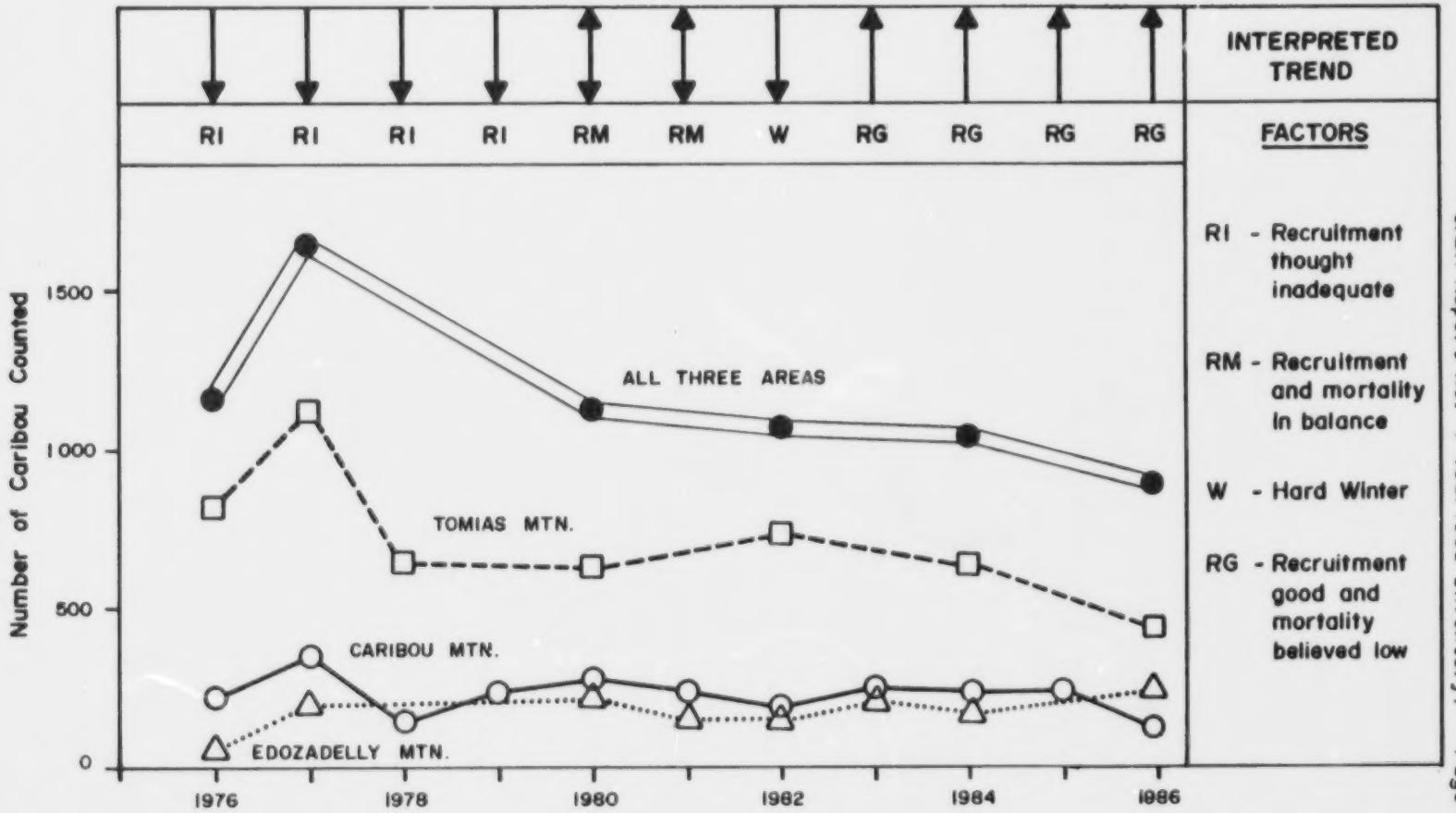


Figure 10. Counts of caribou on selected rut survey areas in Spatsizi Wilderness Park, B.C., as related to interpretations of population trends. The interpretations are based on information in Bergerud (1978a), Jones (1985a), and Hatler (1986a). See text.

the unusually severe winter of 1981-82. Three of seven collared animals (43%) died that winter, and at least two of those and one uncollared animal apparently from causes other than predation. By comparison, there were only two deaths among 67 possible (3%) in three other winters combined (Hatler 1986a). Jones (1985a) noted a drop in both bull and calf ratios in the fall 1982 sample, and speculated that they reflected the negative effects of the 1981-82 winter.

Accordingly, in Figure 10, I show decline as the trend between 1981 and 1982. In addition, I depart somewhat from Jones' (1985a) interpretation of the trend for 1983-85, suspecting at least some increase rather than mere stability over that period. The amended interpretation is based on demonstrably higher fall recruitment figures despite continued negative biases in the samples, the beneficial effects of mild winters after 1982, and relatively low mortality among collared adults during that time.

The major feature of Figure 10 is that there is virtually no relationship between interpreted trend and the observed trend of count data. The most conspicuous peak in numbers, which occurred not only on all three park survey areas but also on adjacent ranges southeast of the park, was in 1977, or about the temporal mid-point of the postulated decline phase. Either the population was not declining, or else the 1977 count was anomalous, resulting from some set of circumstances that a) put a higher than usual proportion of local animals in the uplands surveyed, b) concentrated animals to a greater degree than usual (see Ramey 1984), and/or c) brought animals in from rutting ranges elsewhere. If the count result was due to anomalous conditions, then there is potential for similar factors acting artificially to depress local counts in some years as well. That possibility further reduces the utility of the fall counts as population indicators.

Without the 1977 results, the graphed counts for the three survey areas in Figure 10 would be nearly horizontal across the page, indicating a relatively stable population over the 1976-86 period, or at least relatively stable numbers on the survey areas. The postulated decline in 1982, if it occurred, does not appear on the graph and, indeed, the count at Tomias was higher in that year than in others after 1977. Finally, the count data suggest a slight decline after 1982, in comparison with interpretations of at least stability by both Jones (1985a) and Hatler (1986a) based on other data. Those inconsistent results constitute further evidence that rut survey totals are not reliable indicators of the total Spatsizi caribou population size.

4.5 Summary: Spatsizi Caribou Population Data

Prior to 1976, the best information on numbers and composition of caribou in the Spatsizi Park area was only in the form of local or partial counts of groups that, in the light of present knowledge, were probably not completely representative of, or comparably proportional to, the actual population. From 1976 on, data gathering has been more standardized and consistent, but the samples obtained were nevertheless biased in terms of population composition and were unreliable as indicators of population trend.

Both the historic and recent data described and assessed here have recently been used again to illustrate predation-related patterns of calf abundance and population change in the Spatsizi area over the past 30-40 years (Bergerud and Elliott 1986). Their recruitment/mortality equations and calculations of population trends and rates of increase in the Spatsizi area are based upon differences between successive fall counts, and the assumption that those counts are an accurate and consistent representation of composition and total numbers. The analyses and discussions presented here do not necessarily refute the interpretations of Bergerud and Elliott (1986); rather, they serve to indicate that the available data are inadequate to confirm them.

5. ASSESSMENTS OF CARIBOU INVENTORY THROUGHOUT BRITISH COLUMBIA

5.1 Background

5.1.1 General

Previous pages have analyzed Spatsizi caribou life history information in relation to inventory potential (Section 3), and have assessed existing Spatsizi population data in relation to the results of the inventory analyses. The extent to which the Spatsizi findings may apply to other areas in the province is unknown, therefore I do not claim that I can provide a definitive assessment for all areas. The primary intent in this section is to identify factors that, based both on the Spatsizi results and on other pertinent information, at least ought to be considered either in the planning of surveys or the interpretation of count results in specified areas.

Table 7 lists some common objectives or comparisons in analysis of population data, together with a series of statements about factors such as relative visibility or life history features. Given a particular objective, the statements can be thought of as considerations that, if ignored, may result in real or interpretive errors and biases. The term "season" as used in Table 7 and in the remainder of this section refers to the life cycle seasons for caribou in the Spatsizi area, as depicted in Figure 2.

5.1.2 Population Distinctions

Most of the considerations in Table 7 are drawn directly from Sections 3 and 4 and, in that sense, the table stands as a summary of the inventory and development work at Spatsizi. An exception is the set of listings labeled "general considerations", which refer to the identification and delineation of separate caribou populations throughout British Columbia. There is no agreed-upon definition for the term "population" as it might apply to caribou in the province, and the general terminology applying to associations of caribou is inconsistent. The term "herd", in particular, has been used to denote everything from the group of animals seen together on yonder hill, or the collection of all such groups on all the hills within some set of administrative boundaries, to the summation of all caribou in some much larger geographical area. At some point, "herd" and "population" are the same, and the two terms have frequently been used interchangeably.

Defined simply, a population is "...a set of organisms belonging to the same species and occupying a particular area at the same time" (Brewer 1979). By that definition, nearly any group of caribou could be considered a population, but most such populations would not be meaningful from the stand-

Table 7. A preliminary list of considerations for gathering and interpreting population data for caribou in British Columbia.

I. OBJECTIVE: Determining the trend of one population or comparing data for two or more populations by surveys during the same season in different years.

A. General Considerations

1. Populations cannot be accurately assessed without knowledge of their distributional boundaries at survey time.

B. Data on Numbers

1. Even within the same season, weather conditions or other factors may force different distributions in different years.
2. Weather or other factors may force different aggregation patterns in different years.
3. Weather and background conditions may result in different visibility conditions in different years.
4. In most seasons, the distribution of animals is not homogeneous and numbers are not necessarily proportional to area, especially if only part of the area of distribution is surveyed.
5. Distribution is less stable and predictable in some seasons than in others.

C. Data on Population Composition

1. In some seasons the sexes may be segregated, occupying different habitats with different visibility potentials.
2. In some seasons, parous and non-parous females are distributed differently.
3. In some seasons, successful mothers (females with calves) are distributed differently from those that have lost calves.
4. Recruitment, as measured by surviving young, varies with elapsed time after calving.

II. OBJECTIVE: Determining the trend of a population or comparing data for two or more populations by surveys in different seasons, same or different years.

A. General Considerations

1. Populations cannot be accurately assessed without knowledge of their distributional boundaries at survey time.

B. Data on Numbers

1. Distribution varies such that counts in the same area in different seasons may involve different animals.
2. Dispersion varies such that local densities may be greatly different between seasons.
3. Habitat use varies between seasons, and animals are more visible in some habitats than in others.
4. Aggregation patterns vary between seasons, and large groups may be more conspicuous than small ones.
5. Animal pelage/background contrasts vary seasonally, resulting in differential sightability.

C. Data on Population Composition

1. The degree of sex segregation and differential use of habitats varies between seasons.
2. The distribution of parous and non-parous females relative to each other varies between seasons.
3. The distribution of successful and unsuccessful mothers relative to each other varies between seasons.
4. Recruitment (surviving young) is highest at calving and diminishes thereafter, thus comparisons between seasons may not be valid.

---

point of inventory or management. Stevenson and Hatler (1985) discussed that problem at length, with particular reference to the use of government management unit boundaries as population boundaries. They noted that the administrative boundaries in British Columbia were mostly instituted without regard for, or knowledge of, caribou distribution and movements. Among the management consequences they identified were "incomplete inventories", explaining that "...generally, local managers do not have the budget, time, or mandate to conduct counts in other jurisdictions (adjacent regions, parks), so census efforts often stop at those boundaries even when animal distribution does not." A major conclusion in their study was that "Overall, the initial need regarding caribou numbers...is identification and description of the actual populations present, as defined by biological rather than geographic criteria."

Based on 4 years of radio-tracking, I attempted to distinguish the functionally separate groups of caribou in the Spatsizi area (Hatler 1986a). I found that the homing tendency of many individuals in spring, and their subsequent local movements for some months thereafter, result in maintaining adjacent groups that remain largely separate until early winter. I proposed that the term "herd" be used to designate such associations, of which there appeared to be a minimum of three in the Spatsizi-Tatlatui Parks area. That definition is broader than that of Bergerud and Elliott (1986), who applied "herd" only to those caribou "...that aggregate in the fall on a discrete plateau." Since the three or more herds in the Spatsizi area share a common winter range in at least some winters, I suggested that the term "population" be applied to such a collection of herds.

Whether the above definitions are generally applicable must await the result of similar research in other areas. For the remainder of this discussion, labels for particular groups of caribou are as recorded by others, and I make no claims for or against the biological discreteness of those groups. In the context of inventory, the important point here is that whatever one calls a particular assemblage of animals, comparison of its population parameters between two counts cannot be valid if the whole assemblage is not considered on both counts. That is, the boundary of the survey area, regardless of the vagaries of normal seasonal movements or unusual weather-induced distributions, is essentially that place where the abundance decreases to zero (Andrewartha 1961).

5.1.3 Biological Factors Affecting Inventory

Although Table 7 warns of seasonal variations that might affect survey or interpretational results, it provides no specific information. Table 8

supplements Table 7, characterizing the caribou life history seasons in relation to factors of interest in the context of inventory timing. I again emphasize that Tables 7 and 8 are based primarily on findings in the Spatsizi area, and that local variations in life history may render conclusions inapplicable in some areas. Nevertheless, literature comparisons in Hatler (1986a) suggest that the life histories of different groups of woodland caribou throughout the various mountain habitats of western Canada are similar in many respects.

Figure 11 provides an example of a comparison that was made without regard to some of the possible sources of variation identified in Tables 7 and 8. It shows that an alleged relationship between recruitment and relative abundance of wolves can also be explained as a relationship between apparent recruitment and the season of survey. The depicted areas of low recruitment were mostly surveyed in the pre-rut and rut periods, while the areas of high recruitment were established mostly from summer or winter survey results.

Higher recruitment in summer is an expected result, based on the normal pattern of attrition rather than growth of calf cohorts after the end of calving (Table 7, item 11.C.4). On that basis, higher recruitment in winter than in fall samples is not an expected result. Nevertheless, it was also shown to have occurred among counts in the Spatsizi area (Figure 9, Section 4.3.5), where it was thought to have resulted at least partly from negatively biased fall counts. For the 12 fall samples depicted in Figure 11, the mean recruitment is 7.7 (SD=3.8) while that for 11 samples obtained 2 weeks or more after the rut is 16.6 (SD=6.9). The difference between those two survey periods is statistically significant ($p = .0017$, Mann-Whitney U Test, Siegel 1956).

5.2 Area Assessments

5.2.1 Introduction

Prior to the mid-1970's, there were relatively few surveys specifically for caribou anywhere in British Columbia. That changed in the latter part of the decade, following the pioneering efforts of Bergerud (1978a). In the north, he surveyed much of the northern Skeena Sub-Region and portions of the Omineca Sub-Region in fall 1977, focusing on rut concentration areas, and then attempted surveys in much of the remaining Omineca and Peace Sub-regions in February 1978. The results of those surveys were used to assess and describe population trends and status for more than 30 "herds" in the northern half of British Columbia. For the southern and central portions of the province, caribou population data gathered through at least 1982 have been reviewed by

Table 8. Seasonal considerations for gathering and interpreting caribou population data in British Columbia. The seasons listed are those identified during telemetry studies in the Spatsizi Wilderness Park area (Hatler 1986a).

CARIBOU SEASON (DATES)	REMARKS
Spring Migration	
10-30 May	Both sexes in lowland, timbered habitats, and females moving; sexes mostly segregated.
June through early July	Widely dispersed, especially females; males, non-parous females and unsuccessful mothers moving and aggregating; parous females mostly sedentary, in various habitats; general trend is movement to upland, open habitats (all classes); light winter pelage may be difficult to see against early spring, dead-grass browns.
Summer	
July thru September	All classes mostly in open upland habitats; widely dispersed at first, but becoming more concentrated and aggregated as the period progresses; not all classes in aggregations; dark summer pelage often conspicuous against summer backgrounds.
Rut	
early to mid-October	Aggregated, with local concentrations; often in open upland habitats, but mobile and often unpredictable; all classes not consistently represented in rut concentrations; patchy snow conditions often reduce sightability.
Early Winter	
mid-October through November	May be very concentrated at end of fall migration; all classes of females present, but may be some sex segregation; mostly subalpine habitats, getting lower as period progresses, or in response to heavy snowfall; snowfall may also stimulate movements; good sightability of both animals and tracks on continuous snow cover.
Winter	
December through early May	May be mostly in forest, somewhat dispersed and subject to weather-induced movements; snow conditions may force concentrations in open alpine habitats--all classes present; sightability good in open and semi-open habitats.

Stevenson and Hatler (1985). Their area-by-area analyses included discussions about data quality and inventory deficiencies.

It is beyond the scope of this report to discuss particular results and interpretations or to offer alternative status statements for all of the areas in British Columbia where at least some caribou population data are available. Rather, the objective here is to consider general caribou inventory procedures throughout the province to determine a) their appropriateness in relation to aspects of caribou life history, and b) the likelihood that they provide reliable information on population changes and status. The account for the Spatsizi area (Section 4) serves as an example.

Few reports on inventory of caribou in British Columbia provide explicit descriptions of methods. As inferred from the sources consulted, including Jones (1984a), Hatter (n.d.), Anonymous (1983), and various flight reports, the "standard" caribou survey in the province involves the following elements:

1) Use of an aircraft, usually a jet helicopter.
2) Designation of one or more survey areas, usually defined by lower elevational or open-habitat limits.
3) Total survey coverage of the designated areas by flight patterns judged, in flight, to result in contacting the most animals.
4) Attempted location and enumeration of all animals present in the designated survey areas.
5) Usually, classification of each group encountered to one of four defined levels of detail (see Appendix 1).

Timing has been the major variation between areas. On that basis, the British Columbia Wildlife Branch currently recognizes four categories of caribou surveys: rutting aggregation surveys, winter surveys, summer snowpatch surveys, and post-calving surveys (Hatter n.d.). The following assessments for each are synthesized and summarized from a series of area-specific accounts (Appendix 5) for six administrative regions and sub-regions of the province.

5.2.2 Rutting Aggregation Surveys

Surveys during the rut are widely used in the northern third of the province. I acknowledge that differences in local life history may exempt particular herds or populations from the Spatsizi-derived, negative conclusions about rut surveys (Sections 3 and 4), and that the biological (life history) effects may differ in degree in some years and/or some places. Because there have been no comparable life history studies and no inventory evaluations in the other areas where rut surveys are employed, definitive

Figure 11. Relationship of mid-1970's caribou recruitment data in British Columbia to the seasons of surveys. Seasons are as described in Hatler (1986a):

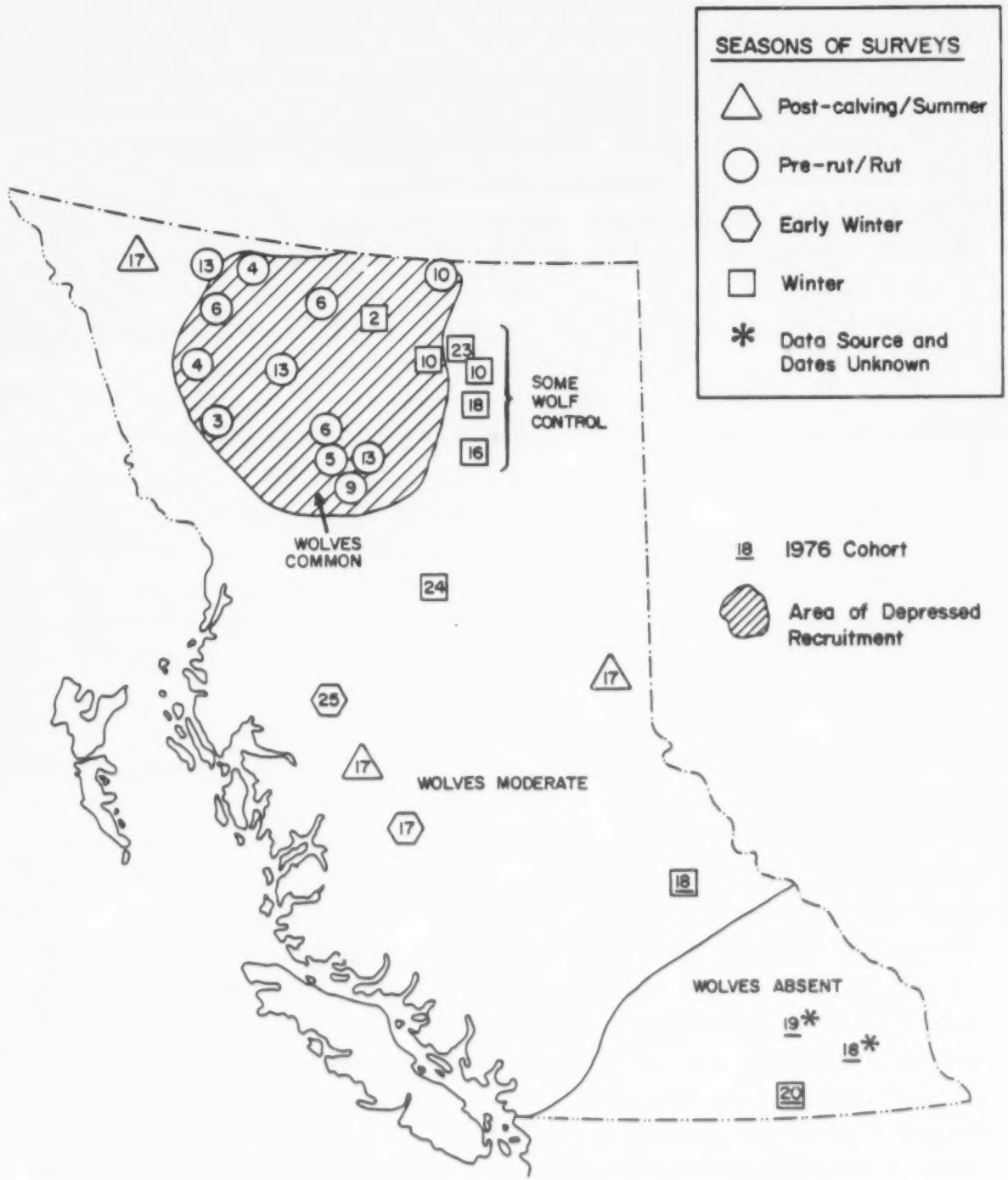
Post-calving/Summer = mid-June through mid-Sept.
Pre-rut/Rut = mid-Sept. through mid-Oct.
Early Winter = mid-October through mid-Dec.
Winter = mid-Dec. through early May.

Except for the seasonal designations, the figure is essentially as presented in three previous publications. Legends from those publications are reproduced below.

Bergerud (1978a, Fig. 19): "Comparison of calf recruitment in British Columbia. An area of depressed recruitment is found in northwestern B.C. Calf recruitment is higher in south, central and northeastern B.C., where wolves are less common."

Bergerud (1983, Fig. 9): "The percent calves in various caribou herds in British Columbia for the 1976 or 1977 cohorts compared to the abundance of wolves. Most figures represent calf percentages in the autumn. Figures east of the Rocky Mountain trench were secured in February 1977."

Bergerud et al. (1984, Fig. 7): "The location of B.C. caribou herds and the percentage of calves in 1976 and 1977; comparison is between herds in northern British Columbia, where wolves were common and the forest was not logged, vs. those in southern British Columbia, where there were few wolves and much of the forest has been logged (Bergerud 1978)." (Note: labelling on this figure was modified to reflect the logging/no logging comparison, but the data were the same.)


SEASONS OF SURVEYS
Post-calving/Summer
Pre-rut/Rut
Early Winter
Winter
Data Source and Dates Unknown
SOME WOLF CONTROL
WOLVES COMMON
WOLVES MODERATE
WOLVES ABSENT
18 1976 Cohort
Area of Depressed Recruitment

assessments are not possible. In most cases, the only available information from the other areas are the inventory data whose reliability is in question. On the basis of some biological factors that potentially affect rut survey results, the following paragraphs consider the generality of the Spatsizi results and discuss apparent anomalies. The focus is on recruitment data, which are usually the primary objective of rut surveys.

Spring Dispersal of Females - Assuming that the spring dispersal is an antipredator strategy (Bergerud et al. 1984), and noting that it and/or solitary calving has been documented repeatedly in telemetry studies of woodland caribou (Shoesmith and Storey 1977; Fuller and Keith 1981; Farnell and Russell 1984; Edmonds and Bloomfield 1984; Marshall 1984; Simpson et al. 1984; Hatler 1986a), there is little reason to expect a different pattern elsewhere. There may be differences in degree, such that local expanses of limited habitat may support higher densities of females at calving. That may be the case for both areas studied by Elliott et al. (1984), Level Mountain and the Horseranch Range, although telemetry studies of local animals captured in fall or winter might show that the total area of calving occurrence was much larger than anticipated for one or both areas. The fact of summer dispersal, at whatever level, sets the stage for the differential movements and behavior between classes that resulted in the rut survey biases identified at Spatsizi.

Differential Mobility of Females - Some cow-calf pairs in the Spatsizi area have made substantial movements in summer. At the individual level, there are a number of extrinsic factors that might cause such movements including disturbance by predators or insects, response to weather factors such as storms or extreme heat, or simply a following/joining response to other caribou groups that happen to pass by. However, from June through mid-October, females with calves in the Spatsizi area generally moved less and stayed closer to calving sites than did those without (Hatler 1986a). That pattern presumably reflects the most secure situation for the calf and, until contrary evidence appears, is assumed to pertain in other areas as well.

Differential Aggregation Patterns Among Females - During calving, significant aggregations of caribou in the Spatsizi area were composed primarily of bulls, yearlings, and barren females (Bergerud et al. 1984). After calving, those groups were joined by other females, particularly those that had lost calves, and there was evidence that such groups comprised the nuclei for later rutting aggregations. Successful mothers mostly remained solitary with their calves, or joined into local, relatively sedentary maternal groups, many of which did not appear in the areas used by rut

aggregations until after the rut period.

The tendency to more solitary behavior among mothers may be another adaptation to enhance calf survival, it being safer to be relatively alone and remote from the more conspicuous aggregations of other classes of animals. Upon loss of a calf, a female may then seek other caribou and better feeding situations (Bergerud et al. 1984), and is therefore more likely to join the non-reproductive aggregations. I have made several similar observations at Level Mountain in summer and fall, i.e, the animals occurring either in small maternal groups or in larger groups with few cow-calf pairs (Hatler 1980a,b). However, on 31 July 1978, an aggregation of more than 300 animals, including many calves, was observed there on a single snowpatch (Hatler 1980a), and R. Page (pers. comm.) reports that 17 of 18 radio-collared calves on Level Mountain were found in one group on one occasion in summer 1980. The generality of aggregation patterns observed at Spatsizi are therefore uncertain.

Differential Fall Migration Patterns Among Females - The relationship between migration and rut is not clear, even at Spatsizi, because there have been few observations of the collared animals in late summer and early fall. Bergerud and Butler (1978) believed that animals migrated from summer ranges to particular areas specifically for the rut, and that most of the animals in a local population were involved. The radio-tracking results have shown otherwise (Hatler 1986a), and have suggested that the fall migration is oriented toward the winter range rather than to rut areas (Section 3.4.2). Thus, rut surveys may often be conducted during migration, whose timing depends on annually varying factors such as weather and locally varying factors such as distance between summer and winter ranges. I can visualize two extreme situations that could result in more representative recruitment figures from fall surveys: 1) A local herd with little or no seasonal migration, i.e., all individuals likely to end up in the same uplands at survey time. 2) A local herd with a very long seasonal migration, possibly requiring earlier and more intensive aggregation among all classes to ensure cohesion. Both situations would probably also feature a reduced degree of dispersal at calving. There are no documented examples of either, although the description in Elliott et al. (1984) suggests that the Horseranch Range Herd may approximate situation 1.

Anomalous Observations - Based on the Spatsizi findings, the expectation for results from a rut survey would be that the recruitment estimate obtained would be lower than the true population figure. One source of evidence supporting the generality of the Spatsizi results is Figure 11, which shows

the fall calf ratios for several herds to be significantly lower than comparable rates obtained for other herds in other seasons. However, in subsequent years some high ratios were obtained in fall counts of some of those same herds, e.g., 25% in 1978 and 16% in 1980 at Level Mountain (Hatler 1980a), 22% on the Kawdy Plateau in 1978 (Hatler et al. 1978), and up to 15% in the Spatsizi area (Hatler 1986b). The question arises as to whether high calf ratios from some fall counts might therefore invalidate the Spatsizi inventory evaluation conclusions.

Even when high recruitment figures are obtained, they could nevertheless be biased below the true values. Such a result, survey recruitment figures consistently lower than actual, would be desirable in the context of conservative management. However, it cannot be depended upon at the current state of knowledge. In all of the above cases, the higher ratios were based on samples that were about 50% or less of suspected population totals, and might therefore have been biased in the opposite direction. That would occur if the survey missed some of the groups derived from post-calving aggregations and for some reason encountered more maternal groups than usual. Unusual weather conditions may sometimes force earlier aggregation and/or movements of maternal groups. For example, a snowstorm prior to survey time might move a large rutting aggregation off a potential survey area, and result in their being replaced by a wave of maternal groups that would have otherwise remained dispersed away from that area. More observations are needed, but there is evidence that, in terms of movements, the rut is a dynamic and therefore unstable time.

5.2.3 Winter Surveys

Winter surveys have been attempted in most areas of the province, with variable success. In all areas the animals spend at least part of the winter in forested habitats, where counting is impractical if not impossible. Winter use of more open habitats near or above timberline seems to be obligatory, in response to characteristics of the snow cover. Such occurrence may be most predictable for the "mountain ecotype" of woodland caribou (Stevenson and Hatler 1985) in the deep snow-belt areas of southeastern B.C. However, the highest counts in some areas to the north (e.g., Cariboo Mountains, Telkwa Mountains, Tweedsmuir Circle, Mount Edziza Provincial Park) have been in late winter (Appendix 5), and significant winter occurrences above timberline have also been recorded in the Spatsizi area (Hatler 1983a, 1986a). Finally, the most dramatic caribou census result in British Columbia history is the count of approximately 2700 animals in a relatively small area of the northern Rockies in January 1969 (Luckhurst 1969).

Although evaluation studies are required for confirmation, two factors combine to suggest that the most reliable census results may be obtainable in winter: 1) Winter occurrence in open, upland habitats appears to be a forced rather than a preferred situation, possibly resulting in maximizing the proportion of animals available for counting and minimizing the area in which they occur, and 2) Sightability of animals and tracks is greatly enhanced on a uniform snow background. A major drawback to scheduling surveys in that season is that the required upland distribution does not occur in all areas in all winters. Although it may occur at any time, as snow conditions dictate, late winter (end of March - early April) seems to be the most predictable.

5.2.4 Summer Snowpatch Surveys

Summer snowpatch surveys were designed and used primarily in Wells Gray Park, although in 1977 one was also attempted near Atlin, in northwestern British Columbia. The technique is based on the observation that on hot summer days, caribou often occur on or near high elevation snowpatches, where they may be readily counted. The potential value of the technique was established in 1970, apparently under ideal conditions. However, those conditions were not duplicated in any survey thereafter, with the result that observers could not confidently distinguish between actual population changes and weather-induced distributional differences. Nevertheless, the most consistent occurrence of radio-collared animals above timberline during the Spatsizi studies was in summer (Section 3.4.1), therefore some survey system in that season may be possible.

5.2.5 Post-calving Surveys

Early summer surveys have been used in the western portions of the Cariboo Sub-Region, and for assessment of early calving success in some northern herds. If only single surveys are to be undertaken in a particular area, a post-calving survey will be of limited usefulness because of the under-representation of bulls and non-parous females in the survey areas.

5.3 Other Inventory Considerations

Previous sections have considered caribou inventory in British Columbia primarily in terms of local differences in the seasonal timing of surveys. The purpose here is to discuss briefly some of the other, more mechanical aspects of gathering, presenting and interpreting caribou inventory data in the province.

5.3.1 Data Gathering

Minimum Counts Vs. Sampling - Minimum counts, sometimes also called "total counts" because the objective is to count all animals present in the survey area, may be adequate for conservative management (Section 3.4.2), but they contribute little to long-term management goals or the needs of research. Presently, there are no objective ways to assess census results. Deficiencies in survey conditions tend to be cited when observed differs from expected, and ignored when the data are supportive. Given the tendency of different classes of animals to segregate and occupy different areas at different times, population estimates are needed to properly evaluate population composition data. The smaller the sample in relation to the total, the less likely that it is representative. While that may seem obvious, most major studies in British Columbia have failed to consider it. Analysis of population status and trend is pointless without credible data on total population size, and that credibility can be objectively established only by measures of statistical confidence. Therefore, a sampling design for caribou inventory is required. A population estimate plus or minus 12% has recently been secured in a Yukon study area, although very high intensity sampling was required (R. Farnell, pers. comm.).

Data Objectives - If population data are being gathered primarily in relation to management for hunting, the fall distribution of the animals in question is important even if surveys in that season are not reliable. Judging from the Spatsizi results, summer surveys would probably produce results more pertinent to local fall management concerns than would those in winter, after the fall migration. Stevenson and Hatler (1985) emphasized that a fundamental inventory need for caribou in southern and central British Columbia was identification of populations and description of their seasonal ranges. Similarly, for most caribou herds or populations in northern British Columbia, seasonal ranges other than those during rut are not well known, and management beyond that season cannot be applied on any informed basis.

5.3.2 Data Presentation

Population Composition Data - The Spatsizi studies have shown that at any given time, the various sex and age classes of caribou may be distributed very differently, making it difficult to obtain representative samples. Such factors as sample size and timing must therefore be considered when data are compared. To facilitate comparisons, a standardized system of classification criteria and data presentation is desirable. The guidelines produced by Jones (1984a) and Hatter (n.d.) are a good start. Appendix 1 lists classification standards and criteria that have been used in the Spatsizi area.

Recruitment Data - Recruitment, which is probably the most important population composition parameter for managers to consider (Bergerud 1978a), may be expressed as the percentage of young-of-the-year among some observed sample of animals, or as ratios of numbers of calves vs. numbers of particular classes of adults (e.g., calves:100 adults, calves:100 females, calves:100 adult females). The percentage-of-total method produces the lowest possible ratio in an absolute sense, by maximizing the negative effect of non-reproductive classes in the sample. Thus, during two years of unusually good production and survival of calves, the percentage of calves would appear poorer in the second year because of the high proportion of yearlings. Further, such good reproductive success and calf survival could combine with low bull mortality, both positive effects, to produce a relatively pessimistic assessment of population performance and status. Davis, Valkenburg, and Boertje (1983) also noted that effect.

Clearly, therefore, the more refined ratios are preferable. The ratio of calves per 100 adult females, i.e., excluding yearlings, would be the best measure of reproductive performance, but is not practical after summer, when yearlings may be difficult to distinguish. The ratio expressions, though more accurately descriptive of survey samples, are nevertheless subject to important biases. Since the different classes of caribou are not uniformly represented in all groups, samples selected by group size or location may not be valid. For example, in Section 3.4.2 it was shown that calves:100 females figures for 1984 rut counts at Spatsizi were probably biased upward by being calculated only from groups completely classified. The only adults not classified were in large groups, and large groups had the fewest calves.

Cumulative Samples - In some studies, observers working in a particular area have combined observations over time, apparently to increase sample size, (Table 1 and Results in Bergerud et al. 1984). Such compilations necessarily include duplicate sightings of individuals, serving only to reinforce whatever biases might be involved in observing those individuals in the first place. Again, the differential distribution and behavior of individuals in relation to differences in sex, age and/or maternal status make it difficult to obtain representative samples.

Incidence of Adult Males - When groups of caribou are being classified, males are commonly categorized by relative antler size. As listed in Appendix 1, the three categories of males for the Spatsizi surveys are large, medium, and small. Large and medium animals are recognizable as males by antler characteristics alone, whereas small males are identified only by reference to external genitalia. However, those terms are subjective and relative and may

mean different things in other areas or to different observers. For example, "small" could be used to refer to all animals not of trophy size, and "large" may designate all animals distinguished by antlers rather than genitals. To facilitate comparisons, a set of standard definitions based on easily recognized criteria should be used throughout the province.

Survey Reliability - Notwithstanding differences in specific methods or timing, some surveys seem to work out better than others. Descriptions and discussions of what went wrong, or right, and statements about the expected reliability of results are important both for future comparisons and in the continuing development of inventory technology. However, some observers go a step farther and expand their minimum count to some new total, including the number or percentage believed to have been missed. As described by Stevenson and Hatler (1985), in the absence of marked animals or a completely homogeneous distribution, such subjective expansion factors are "pure fiction". The facts of a survey are the animals, and sometimes "sign" such as tracks, that are seen. Qualitative designations such as high, medium and low, accompanied by some explanation, constitute sufficient statements of reliability.

5.3.3 Data Interpretation

The Concept of Baseline - The highest historic counts for some areas, e.g., the Muskwa - Prophet area in January 1969 (Luckhurst 1969), the Telkwa Mountains in 1965 (Bergerud 1978a), and possibly Wells Gray Park in 1970 (Ritcey 1970), may have resulted from fortuitous coincidence of surveys at times when animals had been forced into some unusual, but obligatory and conspicuous distribution. Reference to such counts as "baseline" values may foster unrealistic expectations or management goals for particular local areas.

6. CONCLUSION AND RECOMMENDATIONS

Because caribou are mobile and wide-ranging, tending to occur in groups where segregation and differential behavior of various sex, age, and reproductive classes are common, it is difficult to define populations or to obtain representative samples. Telemetry studies in the Spatsizi Wilderness Park area have identified some features of life history that bear on inventory problems, and have provided a means of assessing the reliability of particular census activities and timing. The overall conclusion is that caribou inventory in the province has produced unsatisfactory data since it commenced in the 1970's. However, the applicability of the Spatsizi findings to other areas has yet to be established, and alternative methods are yet to be attempted and evaluated. Following are some recommendations for continued activities directed to assessing the status of caribou populations in British Columbia:

- Although local biological factors may dictate specific methods and timing of caribou inventory, there is a need for some coordination to ensure province-wide consistency and comparability of data produced.

- Where telemetry studies are undertaken, regardless of primary objectives, researchers should take advantage of collared animals to identify potential census situations, define local populations, and evaluate inventory efforts.

- Because the rut has been a focal point for most caribou inventory in northern British Columbia, and because our studies suggest that it may not be the most suitable time, further intensive telemetry study to describe the pattern of activities between late summer and early winter is required. Some points of specific interest are 1) the relationship of maternal status and summer locations to rutting locations, 2) the timing, extent and nature of movements to and from rutting locations, 3) the timing of rut, 4) the nature and stability of rutting aggregations, and 5) the nature of individual occurrence at rutting locations: year-to-year fidelity to particular areas and within-year duration and patterns of use.

- To provide more objective data on population numbers than have been obtainable to date, a sampling design should be developed to replace minimum count systems now being used. The best time for use of such a system in the mountains of British Columbia may be in mid- to late summer, when most animals are widely dispersed in open upland habitats.

- To provide more comparable and meaningful data on population composition, particularly in reference to recruitment, managers and researchers who have made such assessments in fall should attempt other times. At Spatsizi, early winter offers promise because most females have returned from calving areas and the overall dispersion is smallest at that time.

- For areas that have established a "traditional" inventory timing (e.g., post-calving in the Itcha-Ilgachuz area, summer at Wells Gray Park, rut aggregations in most of the north), an abrupt change to some other system without a "usual" count for comparison purposes is not recommended. There has been considerable investment of time and money in past inventories such that paired surveys, old and new systems, may be required for two or more replicates to enable better interpretation of both past and present trends.

- The occurrence of numbers of caribou in open upland habitats in winter may represent an obligatory rather than preferred distribution. Apparently depending mostly on local climatic patterns, such an occurrence may be an annual or only occasional event, but when it occurs it may involve most of the animals over a very large area. A flexible program that enables exploitation of such events when they occur is required, since they may constitute opportunities for actual or near "total counts", which would be valuable as checks against other inventory results, including that from sampling procedures.

7. LITERATURE CITED

Adams, L. 1951. Confidence limits for the Peterson or Lincoln index used in animal population studies. J. Wildl. Manage. 15:13-19.

AIM. 1982. 1982 caribou studies at Baker Mine. Unpubl. Rep. for Dupont of Canada Ltd., AIM Ecol. Consultants Ltd., Surrey, British Columbia. 28pp.

Anderson, D.R., J.L. Laake, B.R. Crain, and K.P. Burnham. 1979. Guidelines for line transect sampling of biological populations. J. Wildl. Manage. 43:70-78.

Andrewartha, H.G. 1961. Introduction to the study of animal populations. Phoenix Books, Univ. Chicago Press, Chicago. 281pp.

Anonymous. 1983. Surveys of caribou, moose, and wolves in northern British Columbia in 1978-79 and 1979-80. Draft Fish and Wildl. Bull., B.C. Ministry of Environ., Victoria. 40pp.

Ballard, W.B., T.H. Spraker, and K.P. Taylor. 1981. Causes of neonatal moose calf mortality in south central Alaska. J. Wildl. Manage. 45:335-342.

Banfield, A.W.F. 1961. A revision of the reindeer and caribou, genus Rangifer. Natl. Mus. Can. Bull. 177 (Biol. Ser. No.66). 137pp.

Banfield, A.W.F., D.R. Flook, J.P. Kelsall, and A.G. Loughrey. 1955. An aerial survey technique for northern big game. Trans. North Am. Wildl. Conf. 20:519-530.

BCFW. 1979. Preliminary caribou management plan for British Columbia. Wildl. Branch, Ministry of Environ., Victoria. 30pp.

BCGC. 1936-1956. British Columbia Game Commission Reports, B.C. Ministry of Environ., Victoria.

BCPW. 1905-1935. British Columbia Reports of the Provincial Warden. B.C. Ministry of Environ., Victoria.

Bergerud, A.T. 1963. Aerial winter census of caribou. J. Wildl. Manage. 27:438-449.

Bergerud, A.T. 1973. Movement and rutting behavior of caribou (Rangifer tarandus) at Mount Albert, Quebec. Can. Field-Nat. 87:357-369.

Bergerud, A.T. 1978a. The status and management of caribou in British Columbia. B.C. Ministry of Environ., Fish and Wildl. Branch Rep., Victoria. 150pp.

Bergerud, A.T. 1978b. Caribou. Pages 83-101 in J.L. Schmidt and D.L. Gilbert (eds.). Big game of North America, ecology and management. Wildl. Manage. Inst., Stackpole, Harrisburg, Pa.

Bergerud, A.T. 1983. The natural population control of caribou. Pages 14-61 in F.L. Bunnell, D.S. Eastman, and J.M. Peek (eds). Symposium on natural regulation of animal populations. For. Wildl. and Range Exp. Sta., Proc. No. 14, Univ. Idaho, Moscow.

Bergerud, A.T., and H.E. Butler. 1978. Life history studies of caribou in Spatsizi Wilderness Park, 1977-78. Special Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 156pp.

Bergerud, A.T., H.E. Butler, and D.R. Miller. 1984. Antipredator tactics of calving caribou: dispersion in mountains. Can. J. Zool. 62:1566-1575.

Bergerud, A.T., and J.P. Elliott. 1986. Dynamics of caribou and wolves in northern British Columbia. Can. J. Zool. 64:1515-1529.

Bergerud, A.T., and F. Manuel. 1969. Aerial census of moose in central Newfoundland. J. Wildl. Manage. 33:910-916.

Bloch, A. 1979. Murphy's law and other reasons why things go wrong. Price/Stern/Sloan Publ. Inc., Los Angeles. 94pp.

Boertje, R.D., and E.L. Young. 1982. Stikine River moose study. Unpubl. Prog. Rep., Alaska Dep. Fish and Game, Juneau. 25pp.

Boonstra, R., and A.R.E. Sinclair. 1984. Distribution and habitat use of caribou, Rangifer tarandus caribou, and moose, Alces alces andersoni, in the Spatsizi Plateau Wilderness area, British Columbia. Can. Field-Nat. 98:12-21.

Bouffard, S.H., and D. Hein. 1978. Census methods for eastern gray squirrels. J. Wildl. Manage. 42:550-557.

Brewer, R. 1979. Principles of ecology. W.B. Saunders Co., Toronto. 299pp.

Burnham, K.P., D.R. Anderson, and J.L. Laake. 1980. Estimation of density from line transect sampling of biological populations. Wildl. Monogr. 72. 202pp.

Cameron, R.D., K.R. Whitten, W.T. Smith, and D.J. Reed. 1985. Sampling errors associated with aerial transect surveys of caribou. Pages 273-284 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Carswell, R. 1975. Wildlife inventory, Gladys Lake Ecological Reserve. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 47pp.

Caughley, G. 1974. Bias in aerial survey. J. Wildl. Manage. 38:921-933.

Caughley, G. 1977a. Analysis of vertebrate populations. Wiley, New York. 234pp.

Caughley, G. 1977b. Sampling in aerial survey. J. Wildl. Manage. 41:605-615.

Caughley, G., R. Sinclair, and D. Scott-Kemmis. 1976. Experiments in aerial survey. J. Wildl. Manage. 40: 290-300.

Chapman, D.G., and W.S. Overton. 1966. Estimating and testing differences between population levels by the Schnabel estimation method. J. Wildl. Manage. 30:173-180.

Cichowski, D. 1986. West-central B.C. caribou research project. Unpubl. Prog. Rep., Faculty of Forestry, Univ. of British Columbia, Vancouver. 45pp.

Curatolo, J.A. 1985. Sexual segregation and habitat use by the Central Arctic caribou herd during summer. Pages 193-198 in T.C Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Davis, D.E., and R.L. Winstead. 1980. Estimating the numbers of wildlife populations. Pages 221-245 in S.D. Schemnitz (ed). Wildlife management techniques manual, 4th Edition. The Wildl. Soc., Washington, D.C.

Davis, J.L., P. Valkenburg, and R. Boertje. 1982. Demography of the Delta caribou herd. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., Vol.1, W-21-2, Job 3.27R, Juneau. 23pp.

Davis, J.L., P. Valkenburg, and R. Boertje. 1983. Demography and limiting factors of Alaska's Delta caribou herd, 1954-1981. Acta Zool. Fennica 175:135-137.

Davis, J.L., P. Valkenburg, and S.J. Harbo, Jr. 1979. Refinement of the aerial photo - direct count - extrapolation caribou census technique. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-17-11, Job 3.24R, Juneau. 23pp.

Davis, J.L., P. Valkenberg, and S.J. Harbo. 1985. Evaluation and refinement of an aerial photo census technique for caribou. Pages 301-302 (abstract only) in Meredith, T.C. and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Eastman, D.S. 1979. Northern inventory - caribou. Unpubl. Flight Rep. for survey in Spatsizi Park, 22 October 1979. B.C. Ministry of Environ., Victoria. 5pp.

Eberhardt, L.L. 1978. Appraising variability in population studies. J. Wildl. Manage. 42:207-238.

Edmonds, E.J., and M. Bloomfield. 1984. A study of woodland caribou (Rangifer tarandus caribou) in west central Alberta, 1979-1983. Alberta Energy and Nat. Resources, Fish and Wildl. Div., Edmonton. 203pp.

Edwards, R.Y. 1954. Comparison of an aerial and ground census of moose. J. Wildl. Manage. 18:403-404.

Elliott, J.P. 1985a. Kechika enhancement project of northeastern B.C.: wolf-ungulate management, 1984-85 annual report. B.C. Ministry of Environ., Wildlife Working Rep. No. WR-13, Fort St. John. 28pp.

Elliott, J.P. 1985b. Muskwa wolf management project of northeastern B.C.: 1984-85 annual report. B.C. Ministry of Environ., Wildl. Working Rep. No. WR-14, Fort St. John. 44pp.

Elliott, J.P., D.S. Eastman, D.F. Hatler, and I. Hatter. 1984. Northern B.C. wolf-caribou study. Draft ms, B.C. Ministry of Environ., Wildl. Branch, Victoria.

Erickson, A.W., and D.B. Siniff. 1963. A statistical evaluation of factors influencing aerial survey results on brown bears. Trans. North Am. Wildl. Conf. 28:391-409.

Evans, C.D., W.A. Troyer, and C.J. Lensink. 1966. Aerial census of moose by quadrat sampling units. J. Wildl. Manage. 30:767-776.

Farnell, R., and D. Russell. 1984. Wernecke Mountain caribou studies. Yukon Wildl. Branch, Whitehorse. 61pp.

Floyd, T.J., L.D. Mech, and M.E. Nelson. 1979. An improved method of censusing deer in deciduous - coniferous forest. J. Wildl. Manage. 43:258-261.

Fong, D.W., W.E. Mercer, M. McGrath, and O. Forsey. 1985. A comparison of strip transect and random quadrat population estimates for Newfoundland caribou herds. Pages 255-264 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Fuller, T.K., and L.B. Keith. 1981. Woodland caribou population dynamics in northeastern Alberta. J. Wildl. Manage. 45:197-213.

Gasaway, W.C., S.D. DuBois, S.J. Harbo, and D.G. Kelleyhouse. 1978. Preliminary report on accuracy of aerial moose surveys. Proc. North Am. Moose Conf. 14: 32-55.

Gasaway, W.C., S.D. Dubois, and S.J. Harbo. 1981. Moose survey procedures development. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Final Rep., W-21-2, Job 1.26R, Juneau. 66pp.

Gates, C.C. 1985. The fall and rise of the Kaminuriak caribou population. Pages 215-228 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Goudreault, F. 1985. Review of caribou census techniques in northern Quebec. Pages 239-254 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Guiguet, C.J. 1959. Field notes, Spatsizi area, July - August, 1959. B.C. Provincial Mus., Victoria. 6pp.

Haber, G.C. 1979. The upper Stikine-Spatsizi wolf-ungulate system, northwestern British Columbia. Rep. No. 1, Spatsizi Assoc. for Biol. Res., Vancouver. 133pp.

Harper, F. 1972. Wildlife values in the southern watershed of the Stikine River in northwestern British Columbia. Unpubl. Rep., B.C. Ministry of Environ., Victoria. 18pp.

Hartman, F. 1962. Report to the Fish and Game Branch on an aerial survey of big game of the Stikine Drainage (Kiniskan Lake to Hyland Post). Unpubl. Flight Rep., B.C. Ministry of Environ., Victoria. 16pp.

Hatler, D.F. 1976a. BCR investigations. Unpubl. Rep. for aerial survey in Fire Flats area, Spatsizi Park area, 13 July. B.C. Ministry of Environ., Smithers. 2pp.

Hatler, D.F. 1976b. Spatsizi caribou surveys. Unpubl. Rep. on aerial surveys, 28-30 September. B.C. Ministry of Environ., Smithers. 10pp.

Hatler, D.F. 1977. Spatsizi - Tatlatui - Lawyers Pass area. Unpubl. Rep. for aerial survey, 7-9 October. B.C. Ministry of Environ., Smithers. 7pp.

Hatler, D.F. 1978. Spatsizi survey. Unpubl. Rep. for aerial survey, 7 October. B.C. Ministry of Environ., Smithers. 3pp.

Hatler, D.F. 1980a. Rut survey, Level Mountain, 1980. Unpubl. Prog. Rep. on wolf-caribou study, B.C. Ministry of Environment, Victoria. 8pp.

Hatler, D.F. 1980b. Wolf-caribou study, Level Mountain phase. Unpubl. Prog. Rep., B.C. Ministry of Environment, Victoria. 31pp.

Hatler, D.F. 1980c. Spatsizi rut surveys. Unpubl. Rep. on aerial surveys, 29-30 September. B.C. Ministry of Environ., Smithers. 5pp.

Hatler, D.F. 1981. 1980-81 Prog. Rep. No. 1, Spatsizi Assoc. for Biol. Res., Smithers, B.C. 24pp.

Hatler, D.F. 1982. Unpubl. Rep. on radio-tracking flight, 7 November 1982. Spatsizi Assoc. for Biol. Res., Smithers, B.C. 6pp.

Hatler, D.F. 1983a. Studies of radio-collared caribou in the Spatsizi Wilderness Park area, British Columbia. Rep. No. 2, Spatsizi Assoc. for Biol. Res., Smithers, B.C. 102pp.

Hatler, D.F. 1983b. Fall caribou surveys, Spatsizi Wilderness Park, 1983. Unpubl. Rep., Spatsizi Assoc. for Biol. Res., Smithers, B.C. 15pp.

Hatler, D.F. 1985. Some thoughts on developing and evaluating inventory methods for caribou. Pap. presented, Workshop on caribou research and management in British Columbia, Kamloops, 6-7 Nov. 1985. In Press.

Hatler, D.F. 1986a. Studies of radio-collared caribou in the Spatsizi Wilderness Park area, British Columbia, 1980-1984. Rep. No. 3, Spatsizi Assoc. for Biol. Res., Smithers, B.C. 202pp.

Hatler, D.F. 1986b. Caribou population composition surveys, Spatsizi Wilderness Park and vicinity, 10-12 October 1986. Unpubl. Rep., Spatsizi Assoc. for Biol. Res., Smithers, B.C. 14pp.

Hatler, D.F., R. Boonstra, and A.R.E. Sinclair. 1976. Eaglenest Creek - Spatsizi Park area Unpubl. Rep. on aerial transect surveys, 25-27 May. B.C. Ministry of Environ., Smithers. 4pp.

Hatler, D.F., K.N. Child, and K. Fujino. 1978. Caribou survey on the Kawdy Plateau. Unpubl. Rep. on aerial survey, 11 October. B.C. Ministry of Environ., Smithers.

Hatler, D.F., and W.G. Hazelwood. 1979. Spatsizi Park winter survey. Unpubl. Rep. for aerial surveys, February. B.C. Ministry of Environ., Smithers. 2pp.

Hatler, D.F., and W.G. Hazelwood. 1984. Mountain goat surveys in Spatsizi Wilderness Park, British Columbia, July 1984. Unpubl. Rep., B.C. Ministry of Lands, Parks and Housing, Victoria. 81pp.

Hatler, D.F., and W.G. Hazelwood. 1985. Mountain goat surveys in the Tatlatui, Spatsizi and Mt. Edziza Provincial Park areas, British Columbia, July 1985. Unpubl. Rep. B.C. Ministry of Lands, Parks and Housing, Victoria. 97pp.

Hatter, I. 1979. The woodland caribou of northern Tweedsmuir Park. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 48pp.

Hatter, I. n.d. Ungulate inventory data system. Unpubl. draft ms, B.C. Ministry of Environ., Victoria. 12pp.

Hazelwood, W.G. 1976. Spatsizi flight report - Cessna 185 - September 26 & 27, 1976. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 6pp.

Hazelwood, W.G. 1979. Spatsizi caribou survey - October 9-12, 1979. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 5pp.

Heard, D.C. 1985. Caribou census methods used in the Northwest Territories. Pages 229-238 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Henshaw, J. 1970. Consequences of travel in the rutting of reindeer and caribou. Anim. Behav. 18:256-258.

Jones, G.W. 1981. Spatsizi Park caribou survey. Unpubl. Rep. on aerial surveys, 9-11 October. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 9pp.

Jones, G.W. 1982a. Spatsizi Park wildlife survey. Unpubl. Rep. on aerial surveys, 28 February - 4 March. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 15pp.

Jones, G.W. 1982b. Spatsizi Park caribou survey. Unpubl. Rep. on aerial surveys, 16 Sept.- 6 Oct. 1982. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 10pp.

Jones, G.W. 1984a. Guidelines for wildlife inventory in provincial parks. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 31pp.

Jones, G.W. 1984b. Spatsizi Park caribou survey. Unpubl. Rep. on aerial surveys, 6-9 October. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 10pp.

Jones, G.W. 1985a. Management of caribou in Spatsizi Plateau Wilderness Park. Paper presented, Workshop on caribou research and management in British Columbia, Kamloops, B.C. 20pp. In Press.

Jones, G.W. 1985b. Spatsizi Park caribou survey. Unpubl. Rep. on aerial surveys, 7-8 October. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 9pp.

Jones, G.W., D. Hebert, K. Fujino, and B. Van Drimmelen. 1981. Tatlatui Park mountain goat survey, 1981. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 7pp.

King, D. 1984. Survey of caribou numbers and distribution in the Cariboo Mountains. Unpubl. Rep. on aerial surveys, March 1984. B.C. Ministry of Environment, Prince George. 18pp.

LeResche, R.E., and R.A. Rausch. 1974. Accuracy and precision of aerial moose censusing. J. Wildl. Manage. 38:175-182.

Lent, P.C. 1965. Rutting behavior in a barren ground caribou population. Anim. Behav. 13:259-264.

Luckhurst, A. 1969. Winter survey report, A.R.D.A. Wildlife Inventory. Unpubl. Rep., B.C. Ministry of Environ., Victoria. (Not seen: cited in Bergerud 1978a).

Luckhurst, A. 1973. Winter survey report, B.C. Land Inventory, (Wildlife Division), Winter 1972-73. Unpubl. Rep., B.C. Ministry of Environ., Victoria. 8pp.

Marshall, R. 1984. First progress report of the Tweedsmuir-Entiako caribou study. Unpubl. Rep., B.C. Ministry of Environ., Smithers. 12pp.

Meredith, T.C., and A.M. Martell (eds). 1985. Proceedings 2nd North American Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal. 327pp.

Miller, F.L., F.W. Anderka, C. Vithayasai, and R.L. McClure. 1975. Distribution, movements and socialization of barren ground caribou radio-tracked on their calving and post-calving areas. Pages 423-435 in J.R. Luick et al. (eds). Proc. 1st Internatl. Reindeer/Caribou Symp., Biol. Pap. Univ. Alaska, Spec. Rep. No. 1.

Mundy, K. 1963. Report to the Fish and Game Branch on the northern survey, 1963. Unpubl. Rep., aerial and ground surveys, August 1963. B.C. Ministry of Environ., Victoria. 9pp.

Mytton, W.R., and L.B. Keith. 1981. Dynamics of moose populations near Rochester, Alberta, 1975-1978. Can. Field-Nat. 95:39-49.

Norton-Griffiths, M. 1976. Further aspects of bias in aerial census of large mammals. J. Wildl. Manage. 40:368-371.

Novak, M., and J. Gardner. 1975. Accuracy of moose aerial surveys. Proc. North Am. Moose Conf. 11:154-181.

Osmond-Jones, E.J., M. Sather, W.G. Hazelwood, and B. Ford. 1977. Wildlife and fisheries inventory of Spatsizi Wilderness and Tatlatui Provincial Parks, British Columbia. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 292pp.

Parker, G.R. 1972. Biology of the Kaminuriak population of barren ground caribou, Part I. Can. Wildl. Serv. Rep. Ser. No. 20, Ottawa. 93pp.

Parr, D.E., and M.D. Scott. 1978. Analysis of roosting counts as an index to Wood Duck population size. Wilson Bull. 90:423-437.

Patric, E.F., G.A. Shaughnessy, and G.B. Will. 1982. A bibliography of wildlife telemetry and radio tracking. Rhode Island Agric. Exp. Sta. Rep. No. 2054, Kingston. 60pp.

Paulik, G.J., and D.S. Robson. 1969. Statistical calculations for change-in-ratio estimators of population parameters. J. Wildl. Manage. 33:1-27.

Pearson, A.M. 1975. The northern interior grizzly bear Ursus arctos L. Can. Wildl. Serv. Rep. Ser. No. 34, Ottawa. 84pp.

Ramey, B.A. 1984. Spatsizi caribou groups in fall: relation between group size and calves. Unpubl. Rep., Forestry 495, Univ. B.C., Vancouver. 33pp.

Reynolds, H.V. 1980. North slope grizzly bear studies. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-17-11, Jobs 4.14R and 4.15R, Juneau. 65pp.

Rice, W.R., and J.D. Harder. 1977. Application of multiple aerial sampling to a mark-recapture census of white-tailed deer. J. Wild. Manage. 41:197-206.

Ritcey, R.W. 1970. Caribou management and inventory in M.A. 12. Unpubl. Rep., B.C. Ministry of Environ., Kamloops. 8pp.

Ritcey, R.W. 1976. Caribou management Plan, Region III. Unpubl. Rep., B.C. Ministry of Environ., Kamloops. 15pp.

Ritcey, R.W. 1982. Summer caribou census - July 29 and 30, 1982. Unpubl. Rep., B.C. Ministry of Environ., Kamloops. 7pp.

Ritcey, R.W., and A. Stewart. 1985. Caribou census - Wells Gray Park, March 25 through March 29, 1985. Unpubl. Rep., B.C. Ministry of Environ., Kamloops. 11pp.

Samuel, M.D., and K.H. Pollock. 1981. Correction of visibility bias in aerial surveys where animals occur in groups. J. Wildl. Manage. 45:993-997.

Sather, M. 1983a. Unpubl. notes, Spatsizi Park caribou surveys, October 1983. B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria.

Sather, M. 1983b. Mt. Edziza Park caribou survey. Unpubl. Rep., B.C. Parks Branch, Ministry of Lands, Parks and Housing, Victoria. 4pp.

Schaefer, D.G. 1978. Climate. Pages 3-10 in K.W.G. Valentine, P.N. Sprout, T.E. Baker, and L.M. Lavkulich (eds). The soil landscapes of British Columbia. B.C. Ministry of Environ., Victoria.

Schwartz, C.C., A.W. Franzmann, and D.C. Johnson. 1982. Black bear predation on moose. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Proj. Rep., W-21-2. Job 17.3R, Juneau. 44pp.

Seip, D. 1986. Preliminary results of the Quesnel Lake caribou study. Unpubl. Rep., Faculty of Forestry, Univ. of British Columbia, Vancouver. 17pp.

Seip, D. 1987. Wells Gray Park caribou study. Unpubl. Ann. Rep., Faculty of Forestry, Univ. of British Columbia, Vancouver. 16pp.

Shoesmith, M.W., and D.R. Storey. 1977. Movements and associated behavior of woodland caribou in central Manitoba. Proc. Intl. Congr. Game Biol. 13:51-63.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., Inc., N.Y. 312pp.

Simpson, K., K.B. Hebert, and G.P. Woods. 1984. Mountain caribou (Rangifer tarandus caribou) ecology in the Columbia Mountains of British Columbia. Unpubl. Rep., B.C. Ministry of Environ., Nelson. 38pp.

Siniff, D.B., and R.O. Skoog. 1964. Aerial censusing of caribou using stratified random sampling. J. Wildl. Manage. 28:391-401.

Stevenson, S.K., and D.F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia. B.C. Ministry of For., Land Manage. Rep. No. 23, Victoria. 355pp.

Stott, R.S., and D.P. Olson. 1972. An evaluation of waterfowl surveys on the New Hampshire coastline. J. Wildl. Manage. 36:468-477.

Thomas, D.C. 1969. Population estimates of barren ground caribou, March to May 1967. Can. Wildl. Serv. Rep. Ser. No. 9, Ottawa. 43pp.

Valkenberg, P., D.A. Anderson, J.L. Davis, and D.J. Reed. 1985. Evaluation of an aerial photocensus technique for caribou based on radio-telemetry. Pages 287-300 in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Van Drimmelin, B. 1983. 1983 inventory of the Kawdy-Jennings-Level Mountain caribou population. Unpubl. Rep., B.C. Ministry of Environ., Smithers. 21pp.

Walker, T.A. 1978. Comments and tabulation of caribou observations and counts, 1948-59, in the Spatsizi Wilderness Park area. Unpubl. data and notes from diary, T.A. Walker, Smithers, B.C.

Watson, G.W., and R.F. Scott. 1956. Aerial censusing of the Nelchina caribou herd. Trans. North Am. Wildl. Conf. 21:501-509.

Whitten, K.R. 1985. Censusing the Porcupine caribou herd: practical application of aerial photo techniques. Page 285 (abstract only) in T.C. Meredith and A.M. Martell (eds). Proc. 2nd North Am. Caribou Workshop, Val Morin, Quebec. McGill Subarctic Res. Pap. No. 40, McGill Univ., Montreal.

Wood, R.E. 1976. Movement and populations of brown bears in the Hood Bay drainage of Admiralty Island. Alaska Dep. Fish and Game, Unpubl. Pittman-Robertson Prog. Rep., W-17-5, W-17-6 and W-17-7, Job 4.7R, Juneau. 10pp.

* * * * *

Appendix 1. Criteria and standards for distinguishing and describing the various sex and age classes of caribou for fall demographic studies in the Spatsizi Wilderness Park area, British Columbia (adapted from Hatler 1983a and Jones 1984a).

CLASSIFICATION CRITERIA

Large Bull - with large, mature complement of antlers, usually with a palmated brow tine ("shovel").
Medium Bull - distinguishable as a male in having larger antlers than females, but with brow tines not palmated.
Small Bull - not distinguishable from females by antler development; classified on basis of lack of black vulval patch when viewed from the rear.
Adult Female (yearling or older) - with a calf, and/or with a black vulval patch when viewed from the rear.
Calf (young-of-the-year) - considerably smaller than adults, usually with darker pelage and with short, velvet antlers (up to 30 cm long, and usually single spikes, but occasionally forked). Note: male and female calves can be distinguished by presence/absence of the vulval patch, as described for adults.
Unidentified Adult - animal not seen well enough to determine sex, but known not to be a calf.
Unclassified - neither age nor sex determined.

CLASSIFICATION STANDARDS

Level 1: calves and unclassified adults.

Level 2: calves, large bulls, and unclassified adults.

Level 3: male and female calves, bulls, and adult females.

Level 4: calves (sexed, if possible), bulls (large, medium, and small), and adult females.

* * * * *

Appendix 2. Details of caribou census and evaluation activities, Spatsizi Wilderness Park area, British Columbia, 1981-1986.

Since the first animals were radio-collared, in late October 1980, there have been six series of surveys during the rut. The following outlines both the details of the census work carried out and the extent and nature of attendant evaluation studies during each. Evaluation activities were carried out by Spatsizi Association for Biological Research (SABR) unless otherwise noted.

1981

Surveys: Complete helicopter census of Caribou Mountain, interrupted by weather on 9 October, but completed on 10 October; partial helicopter surveys on Tomias Mountain (in passing) and on Edozadelly Mountain (emphasis on area within park) on 11 October; surveys carried out by Parks Branch (G. Jones) and SABR (D. Hatler).

Evaluation: 9 collared animals, of which 7 were females; radio-tracking flights in fixed-wing aircraft on 8 and 12 October; use of helicopter to determine maternal status of one collared female outside the survey area on 10 October.

1982

Surveys: Fixed-wing reconnaissance of general survey areas on 26, 27, and 29 September and 1 October; complete helicopter census of Caribou Mountain, Tomias, and Edozadelly survey areas on 4-6 October; surveys by Parks Branch (Jones), assisted by Wildlife Branch (B. van Drimmelen) and A.T. Bergerud.

Evaluation: Only 4 collared animals present, all females; 3 radio-located during reconnaissance flight on 29 September (census crew only).

1983

Surveys: Several fixed-wing reconnaissance surveys in general area, late September through 6 October (Parks Branch); helicopter census of both Caribou Mountain and Edozadelly survey areas on 9 October; due to last-minute need for experienced observer to lead survey, only SABR (Hatler) available, assisted by M. Sather and T. Osmund-Jones (Parks Branch).

Evaluation: 28 collared animals, including 4 males; evaluation activities relegated to secondary priority because of survey staffing problem; fixed-wing tracking flight delayed by bad weather--commenced late on 10 October and terminated by bad weather before complete coverage could be obtained; helicopter not available to confirm status of females not seen during surveys.

1984

Surveys: Helicopter census of Caribou Mountain, Tomias, and Edozadelly survey areas, 6-9 October; survey team at Caribou Mountain, 6-7 October, was Parks Branch (Jones) and Wildlife Branch (I. Hatter)--at other two areas on 8-9 October, also included SABR (Hatler).

Evaluation: 26 collared animals, including 4 males; complete fixed-wing tracking flight in general area, 5-7 October, i.e., before and during census on Caribou Mountain; helicopter survey to observe and confirm maternal status of collared females on Caribou Mountain area on 7 October and at Tomias on 8 October.

Appendix 2 (continued)

1985

Surveys: None originally planned, but last minute funding enabled complete helicopter census of Caribou Mountain and partial census of Tomias area on 7-8 October; survey by Parks Branch (Jones, J. Hopkins) assisted by Wildlife Branch (R. Marshall).

Evaluation: Inadequate budget and a scheduling conflict combined to prevent evaluation of the above survey.

1986

Surveys: Complete helicopter census of Caribou Mountain, Tomias, and Edozadelly survey areas, 10-12 October; survey by SABR (Hatler) assisted by Parks Branch (J. Ferguson).

Evaluation: Fixed-wing tracking flight over the area on 10 October; use of the helicopter during and after the survey to confirm locations of the collared animals during the survey and to determine the maternal status of most of the collared females.

* * * * *

Appendix 3. Distribution and status of radio-collared caribou during rut surveys, 1981-1986, Spatsizi Wilderness Park and vicinity, British Columbia.

The extent of surveys, the level of evaluation intensity, and the size of the collared sample all varied among years (Appendix 2). The following compilation documents the detailed status and occurrence of the collared animals at survey time over the study years, and thereby serves as the factual basis for the summary data presented in the evaluation section (3.2.2) of this report. Interpretational problems and information gaps are also identified, and a general assessment of the evaluation effort for each year is provided.

Individual animals are identified by the numbers assigned to them at capture. The letter prefix indicates the time and general location of original capture, as follows: A - late October 1980, Caribou Mountain (N=15); B - late October through early November 1982, Caribou Mountain (N=35); C - June 1983, Fire Flats (N=2), D - March 1984, Caribou Mountain (N=3);E - March 1985, Caribou Mountain (N=3), F - June 1986, Caribou Mountain,(N=1). The October locations of those animals are listed either as one of three designated survey areas, Caribou Mountain/Marion (CM), Tomias Mountain (T), or Edozadelly Mountain (E), or as "other" (O) if an animal was not at one of those areas. Although the surveys were limited to the open alpine and subalpine habitats at and above 1525 m, occurrences on lower slopes adjacent to the open survey areas are considered here as within the survey areas. Such occurrences are designated by asterisks, one of which (*) indicates that an animal was known present in a survey area, but was suspected to have been in an obscuring habitat below timberline at survey time; two asterisks (**) indicate a known occurrence below timberline at survey time. Assessments of the evaluation efforts are based on consideration of the size of the collared sample, the elapsed time between census and evaluation, and the detail of the census observations.

1981

Number of Active Collars - 9 (7 females, 2 males)

Distribution at Survey Time -

Females with calves: CM-0; T-0; E-0; O-2 (A04, A07).
Females without calves: CM-4 (A00, A01, A02, A03); T-1 (A08*); E-0; O-0.
Males: CM-2 (A14, A16); T-0; E-0; O-0.

Interpretation - 7 of 9 collared animals were on or near the survey areas; of the areas actually surveyed, only CM had collared animals present (6), and 5 of those were seen during the survey; among the collared animals, only the 2 males and 5 females without calves were on or near the survey areas.

Assessment - The evaluation effort consisted of fixed-wing radio-tracking flights before and after the census, as well as identification and close observation of most of the collared animals (7 of 9) from the helicopter during the census. The overall effort was good, marred only by the relatively small sample size.

1982

Number of Active Collars - 4 (all females).

Distribution at Survey Time -

Females with calves: CM-0; T-0, E-0, O-1 (A00).
Females without calves: CM-2 (A02, A08); T-0; E-0; O-1? (A04).

Appendix 3 (continued)

Interpretation (1982) - Apparently only 2 of 4 animals were on survey areas, although the actual location of A04 was not determined. She was not at CM, was not seen or otherwise contacted at T, and there is no reason to suspect that she might have been at E; of the 2 known present on an area surveyed, 1 (A08) was seen; the only female still with a calf on 27 September was not on a survey area at that time.
Assessment - The applicable tracking flight was incidental to a reconnaissance survey, and was not extensive outside the survey areas. Further, it was 7 days prior to the helicopter census; locations of collared animals during or after the census were not confirmed. Those facts plus the small sample size make the 1981 census evaluation effort the poorest overall.

1983

Number of Active Collars - 28 (24 females, 4 males)

Distribution at Survey Time -
Females with calves: CM-1 (B09); T-0; E-0; O-1 (B23).
Females without calves: CM-9 (A00, A02, B02, B03, B04, B07, B11, B12, B13); T-1 (B15); E-0; O-10 (A04, A08, B08, B10, B17, B18, B19, B21, B24, C38).
Females, maternal status unknown: CM-1 (B14*); T-1 (B20), E-0;O-0.
Males: CM-1 (B32*); T-1 (B35*); E-0; O-2 (B29, C39).

Interpretation - Only 13 of 24 collared females and 2 of 4 collared maleswere in survey areas at survey time; of 12 animals present in an area actually surveyed (CM), only 8 were seen on the survey; of 2 females known to have had calves at survey time, 1 was in a survey area and 1 was not; 2 other females were known or suspected to have produced calves in 1983,and were not specifically documented as having lost them either in a subsequent summer survey, or in October--both were on or near a rut survey area.
Assessment - Although the sample size was the largest in the 4 years of study, the overall proportion of females with calves was small, thus hampering comparisons of occurrence in relation to maternal status; weather both delayed the post-survey radio-tracking flight to more than 24 hours after the survey and prevented locating all the animals, and the helicopter was not available to locate and closely observe females whose maternal status was unknown; the evaluation flight was intensive enough over the survey areas to confirm that the missing animals were not in those areas, but not extensive enough to determine the actual locations for 8 (29%) of them; thus, although providing more information than the evaluation effort in 1982, that in 1983 warrants only a "fair" success rating.

1984

Number of Active Collars - 26 (22 females and 4 males)

Distribution at Survey Time -
Females with calves - CM-3 (B03**, B07, B09); T-1 (B19), E-1 (D40); O-4 (B20, B24, D41, D42).
Females without calves - CM-7 (A00, A02, A04, A08, B04, B14**, C38); B10**, B11*, B15); E-0; O-3 (B08, B18, B21?).

Appendix 3 (continued)

Distribution at Survey Time (1984, continued) -
Males - CM-1 (B32); T-3 (B29, B35, C39); E-0; O-0.

Interpretation - No. B09 was seen in July, apparently without a calf, but had one at heel in October; it is assumed that the calf was hers and that we simply missed seeing it during the July fixed-wing flight. No. B21 was not seen in June, July, or October, but was seen without a calf in November; it is assumed here that she was also without a calf in October, since most losses occur before then (Hatler 1986a). Of the 26 collared animals, 19 were on or near survey areas during the general survey period and at least 17 were so distributed at survey time; 2 animals, 1 male and 1 female, apparently moved off and away from the Tomias area between the tracking flight (5 October) and the survey (8 October). Of 9 females with calves, 5 were on or near survey areas, although 1 was below timberline. Of the 19 animals on or near survey areas, 14 were actually in open areas and 13 of those were seen during the survey.

Assessment - With a relatively large collared sample, evaluation tracking flights just before and during the census flights, and additional use of the helicopter to determine the status of some females, the 1984 evaluation effort was the best overall.

1985

Number of Active Collars - 25 (22 females, 3 males).

Distribution at Survey Time - Unknown--limited survey and no evaluation.

1986

Number of Active Collars - 22 (21 females, 1 male).

Distribution at Survey Time -
Females with calves: CM-2 (B09, E43); T-1 (B11); E-1 (B24); O-4 (B08, B18, D41, D42).
Females without calves: CM-7 (A00, A02, A08*, B04, B14, E44, F46); T-4 (B10, B15, B19, D40); E-0; O-0.
Females, maternal status unknown: CM-0, T-0, E-0, O-2 (B21, E45).
Males: CM-0, T-1 (C39); E-0; O-0.

Interpretation - No. F46 was captured on the CM area in June 1986, and lost her calf as a result of the capture. Her without-calf occurrence on the CM area in October may therefore be an artificial result, and it is not included in compilations relating to rut area selection. The two females whose maternal status in October was unknown both had calves when last seen (mid-June).

Of 8 females known to be with calves in October, 4 were on survey areas and 4 were not. Of 16 animals on the survey areas, 14 were in open habitats, but only 9 were seen.

Assessment - The collared sample was adequate, the survey covered all three survey areas, and the evaluation included both a fixed-wing tracking flight before the survey and opportunity to monitor locations and maternal status of collared females during the survey. The evaluation is rated good overall.

* * * * *

Appendix 4. History and description of observations and surveys producing data on caribou numbers and composition in Spatsizi Wilderness Park, British Columbia. The caribou seasons (Hatler 1986a) are spring migration (M), summer (S), pre-rut (P), rut (R), fall migration/early winter (F), and winter (W); survey mode includes observations from the ground (G) and from the air in either fixed-wing aircraft (F) or helicopters (H); the nature of data columns identify the degree of focus and effort on caribou, distinguishing between observations that were made incidental (I) to non-survey activities in the area, surveys that were general for all wildlife in the area (G), and surveys specific for caribou (C). Caribou surveys are further distinguished as reconnaissance to determine distribution and/or habitat use (d), and surveys for numbers (n) or composition (c).

Source[a]	Dates Mo./Yr.	Caribou Season	Surv. Mode	Nature of Data Obs.	Area[b]	No. Caribou N	% Clsfied[c]	Calf Ratios % of Clsfied	Per 100 Females
Walker (1978)	8- 9/48	S	G	I	L	102[d]	5	0	-
Walker (1978)	8- 9/49	S,P	G	I	L	329[d]	12	25	-
Walker (1978)	8- 9/50	S	G	I	L	50[d]	23	0	-
*Walker (1978)	6-10/51	S,P	G	I	L	105[d]	34	25	-
*Walker (1978)	8- 9/52	S	G	I	L	43[d]	70	23	-
*Walker (1978)	7-10/53	S-R	G	I	L	265[d]	33	15	-
*Walker (1978)	8- 9/54	S	G	I	L	152[d]	18	30	-
*Walker (1978)	7- 9/55	S	G	I	L	549[d]	9	38	-
*Walker (1978)	7- 9/56	S,P	G	I	L	175[d]	37	28	-
*Walker (1978)	7-10/57	S-R	G	I	L	204[d]	26	7	-
*Walker (1978)	7-10/58	S-R	G	I	L	113[d]	19	24	-
Guiguet (1959)	6- 9/59	S,P	G	I	L	550	8	26	-
*Hartman (1962)	7- 8/59	S	G	I	L	151	26	13	-
*Mundy (1963)	8 /62	S	F	G	P	117	33	25	-
Harper (1972)	8 /63	S	G	G	L	54	65	28	-
*Luckhurst (1973)	2 /72	W	H	G	P	307	0	-	-
*Lau (n.d.)[e]	3- 4/73	W	F	G	Tr	623	0	-	-
*Fleming (n.d.)[e]	7 /73	S	G	I	L	74	?	1?	-
*Farnell (n.d.)[e]	8- 9/73	S,P	G	I	L	162	?	6?	-
*Carswell (1975)	10 /74	R	G	I	L	150	?	2?	-
*Foster (1975)[f]	7- 8/75	S	G	G	L	58	76	7	13
Hatler et al. (1976)	7 /75	S	H	I	L	342	87?	0?	-
*Hatler (1976a)	5 /76	M	F	G	Tr	76	0	-	-
*Osmond-Jones et al. (77)	7 /76	S	H	I	L	366	100	2	-
	5 -9/76	M-P	F,G	G	L	1054[d]	74	6	9

Appendix 4 (continued)

Source[a]	Dates Mo./Yr.	Caribou Season	Surv. Mode	Nature of Data Obs.	Area[b]	No. Caribou N	% Clsfied[c]	Calf Ratios % of Clsfied	Per 100 Females
Hazelwood (1976)	9 /76	P	F	C:d	C	1112	0	-	-
Hatler (1976b)	9 /76	P	H	C:n,c	CTEO	1179	57	7	-
Sinclair (n.d.)[e]	3 /77	W	F	G	Tr	313	0	-	-
Bergerud et al. (1984)	5 /77	M	F?	C:n,c	L	252[d]	100	0	-
Bergerud et al. (1984)	6- 7/77	S	G	C:n,c	L	740[d]	100	?	6
Hatler (1977)	10 /77	R	H	C:n,c	CTEO	1669	84	7	-
Hatler (1978)	10 /78	R	F	C:n,c	CTO	821	64	13	-
Hatler & Hazelwood (1979)	2 /79	W	H	I	P	112	100	21	-
Hazelwood (1979)	10 /79	R	H	C:n,c	CT*	349	100	11	17
Eastman (1979)	10 /79	F	H	C:n,c	C	227	100	7	9
Hatler (1980c)	9 /80	P	H	C:n,c	CTEO	1124	100	13	-
Hatler (1981)	1 /81	W	H	I	P	308	100	21	-
Jones (1981)	10 /81	R	H	C:n,c	CT*E	457	100	8	17
Jones (1982a)	2 -3/82	W	H	G	P	438	100	16	-
Jones (1982b)	10 /82	R	H	C:n,c	CTE	1075	100	10	14
Hatler (1982)	11 /82	F	H	C:c	C	206	95	15	-
Hatler (1983b)	10 /83	R	H	C:n,c	CE	446	100	15	24
Hatler & Hazelwood (1984)	7 /84	S	H	I	P	188	91	24	-
Jones (1984b)	10 /84	R	H	C:n,c	CTE	1041	100	13	27
Jones (1985b)	10 /85	R	H	C:c	CT*	693	100	12	21
Hatler (1986b)	10 /86	R	H	C:c	CTE	884	94	15	24

[a]Asterisks indicate sources used by Bergerud (1978a) to describe population trends and status of Spatsizi caribou.

[b]Area of coverage: L=local (restricted to a relatively small area during any 1-3 day period); P=partial, in relation to total park area; Tr= transects over most of the park area; for surveys during pre-rut and rut, observations after 1975 restricted to specified areas (C=Caribou Mt., T=Tomias Mt., E=Edozadelly Mt., O=Other; an asterisk indicates only partial coverage of a particular survey area.

[c]Per cent of N classified to at least adult-calf distinction (Level 1 in Appendix 1).

[d]Cumulative totals over a period of days or weeks, with repetition in one or more areas.

[e]Apparently personal communication references; cited by Bergerud (1978a).

[f]Cited in Carswell (1975).

Appendix 5. Area-specific assessments of caribou inventory in British Columbia, as related to aspects of life history.

Based on the more detailed findings and conclusions presented for the Spatsizi area (main text, Sections 3 and 4), the objectives here are a) to outline some potential pros and cons of the caribou inventory timing and methods used elsewhere in the province, and b) to assess the reliability of the resulting survey data for indicating population changes in those areas. The conclusions presented below, with separate accounts for each of the administrative regions or sub-regions that have gathered caribou population data, are based on and documented in relation to Tables 7 and 8 in Section 5.1.

Thompson-Nicola Sub-Region

As described in Stevenson and Hatler (1985), the most intensive and regular caribou research and inventory in the province prior to the late 1970's was that conducted in the Wells Gray Park area. Based on observations during the mid-1960's, the inventory system developed there was an attempted total count and classification, by helicopter, of animals on and near high elevation snow patches on a hot day in July (Ritcey 1970, 1976). A high count was obtained with that method in 1970, but not in subsequent years (see account in Stevenson and Hatler 1985).

Pros: Most classes available in open, upland habitats (Table 8); group sizes not unduly large (Table 8).

Cons: Definition and distribution of total population not known (Table 7: I.A, II.A); Varying weather effects on distribution, aggregation patterns, and visibility (Table 7:I.B.1-3); only partial area coverage in some years (Table 7: I.B.4).

Reliability: Apparently poor; observed differences in numbers between surveys could not be demonstrated to be unrelated to differences in survey conditions.

The Wells Gray animals have recently been censused in late winter. The first attempt in that season resulted in a survey cost approximately 50% higher than that in summer, but produced the largest number since the high count in summer 1970 (Ritcey and Stewart 1985). The pros and cons of winter surveys in that area should be the same as for others in southern B.C. (Kootenay Region, below). In the absence of certain information on the affinities and annual distribution of the total, functional population in the area (Table 7: I.A, II.A), comparisons between the winter survey and those in summer are subject to the considerations listed under item II in Table 7.

More recently, Seip (1987) conducted a helicopter survey of uplands throughout Wells Gray Park in March, obtaining a minimum total count and then calculating a total population estimate by "correcting" the count total on the basis of the proportion of marked (radio-collared) animals seen during the survey. The details of that methodology and of the actual count results have not been provided, therefore further assessment here is not possible. A potential concern is that all of the marked animals were captured in the habitats and season of survey, thus if there are any with a different wintering strategy, they may not have been represented in the counts. In addition, it is not clear whether the marked animals were distributed in the population in accordance with the assumptions requisite for Lincoln Index estimation procedures (see Davis and Winstead 1980).

Appendix 5 (continued)

Kootenay Region

The only non-incidental census efforts in the Region have been those in the northern Monashee Mountains in relation to studies by Simpson et al. (1984). In late March they used fixed-wing aircraft to locate and count animals in alpine parklands within their study area, and then returned to occupied areas with a helicopter to classify the animals tallied. Their final population estimate was a Lincoln Index expansion of the total number seen, based on a small sample of radio-collared animals.

Pros: When forced into open, upland habitats in winter, animals are visible, are concentrated in relatively small areas, and all classes are usually present (Table 8); based on radio-tracking and study area definition, the distribution at survey time was reasonably well known (Table 7: I.A); snow conditions in late March in that area may be similar enough from year-to-year, in relation to caribou mobility, so that the altitudinal distribution in that season may be the same every year (Table 7: I.B.1-3).

Cons: Only partial surveys undertaken on some occasions (Table 7:I.B.4); snow conditions relative to caribou needs may vary enough from year-to-year so that distribution (altitudinal/local) and aggregation patterns may vary (Table 7: I.B.1-2); given the range of observed group sizes in late winter (1-25), the Lincoln Index expansion based strictly on total numbers is risky.

Reliability: Promising; animals and tracks are conspicuous in alpine areas in winter, therefore if the population is defined and its distribution is known, and if the alpine occurrence is obligatory because of snow conditions, readily comparable counts may be obtained (replicate surveys and evaluations based on locations of collared animals are required for substantiation).

Cariboo Sub-Region

In the Quesnel Highlands area, caribou have recently been censused, by helicopter coverage of designated study area uplands in early March (Seip 1986). As at Wells Gray, a minimum total count procedure was used, but with the final result "corrected for sightability" on the basis of the proportion of radio-collared animals seen during the survey. The assessments given for that specific methodology in the Wells Gray discussion, and for the late winter timing in the Kootenay Region account, above, also apply here.

Surveys in the Itcha, Ilgachuz, and Rainbow Mountains in recent years have been primarily in June or early July, after calving, followed in at least some years by comparative counts in other seasons (Stevenson and Hatler 1985, Cichowski 1986). I have seen no detailed account of the rationale or methods of those surveys, but understand those in summer to be similar to the fall Spatsizi surveys described earlier, i.e., minimum total counts, by helicopter, with emphasis on recruitment data. The comparative surveys in any given year apparently cover only a selected portion of the total population area, and are designed to provide sample information on the incidence of classes that do not occur in the summer survey areas. Those partial surveys are subject to concerns expressed in Table 7 (I.A, I.B.4, II.B.1,4, II.C.1-4). The assessments listed below refer to the summer surveys.

Pros: Many animals available in open, upland habitats (Table 8); group sizes not unduly large (Table 8).

Cons: Distribution of entire population not known (Table 7: I.A, II.A); summer background and visibility conditions may vary (Table 7: I.B.3); there is some segregation of sexes and possibly between other classes in early

Appendix 5 (continued)

summer (Table 7: I.C.1-3); early summer calf ratios are not, in themselves, meaningful measures of recruitment (Table 7: I.C.4); summer distribution is widely dispersed, resulting in maximal flying costs.

Reliability: At least fair, depending on objectives; early summer counts in the mountains are useful in establishing the minimum size of the breeding female component, and in indicating calving success and/or early calf abundance, but are of limited usefulness in measuring population changes because males and some other classes of animals are under-represented.

Skeena Sub-Region

Winter Surveys

For caribou in the southern part of the sub-region, the Telkwa and Tweedsmuir Circle Herds of Bergerud (1978a) and Stevenson and Hatler (1985), the highest counts have been in late winter. However, past data for the Telkwa animals and radio-tracking results for the Tweedsmuir animals in recent years (Marshall 1984) indicate that all or most individuals in both herds may remain below timberline in at least some winters. Therefore, inventory comparisons between or within winters are apparently subject to most of the weather-induced discrepancies in distribution and aggregation patterns identified for the Spatsizi area.

Caribou in Mt. Edziza Provincial Park have been surveyed both in fall and late winter. As with the Telkwa and Tweedsmuir Circle animals, the highest counts have been obtained in winter, and the discussion and assessment for those areas may also apply to Edziza. Possibly late winter snow conditions at Edziza are more predictable, forcing an obligatory alpine occurrence every year, in which case the winter survey potential is more like that described above for the Monashee Mountains (Kootenay) and Wells Gray Park (Thompson-Nicola). Comparisons of the winter counts at Edziza with fall results either from there or elsewhere are subject to the concerns listed under Item II of Table 7.

Pros: When forced into open, upland habitats in winter, animals are visible, are concentrated in relatively small areas, and all classes are usually present (Table 8).

Cons: Weather conditions may force different distributions and aggregation patterns between surveys (Table 7: B.1-3); the total distribution of any particular herd/population has not been known at the time of survey (Table 7: I.A), and only portions of the area have been covered in some years (Table 7: I.B.4).

Reliability: For those winters with significant alpine occurrence, representative counts may be obtained.

Summer Surveys

Early summer (post-calving) surveys have been conducted in the Spatsizi area (Bergerud *et al.* 1984), and at Level Mountain and the Horseranch Range (Elliott *et al.* 1984), but the objective for those surveys was assessment of calving performance rather than documentation of population size or demographics. Bergerud (1978a) surveyed caribou in the Atlin area in mid-August 1977. The total distribution of caribou in the area was not known at the time of survey (Table 7: I.A), and some sightability problems were apparently encountered. The pros, cons, and reliability of the Atlin survey are about as outlined for the summer surveys in the Wells Gray Park area (above). However, a major impediment with the Atlin data is that all possible comparisons are between-seasons, raising all of the concerns outlined under

Appendix 5 (continued)

Item II in Table 7. There have been no other official summer surveys in the sub-region, although Hatler and Hazelwood (1984, 1985) recorded numerous incidental sightings of caribou during mid-July mountain goat surveys in the Spatsizi and Tatlatui Park areas, and were impressed with the conspicuousness of the animals at that time.

Pros: From about mid-July, all classes available in open, upland habitats; group sizes not unduly large; dark summer pelage fairly conspicuous against summer colors (Table 8).

Cons: Local population may be widely dispersed (Table 8), requiring maximal flying expense and effort to cover total survey area; weather or other factors may result in varied distribution, aggregation, and sightability from year-to-year (Table 7: I.B.1-3); distribution of females may vary with maternal status (Table 7: I.C.2-3).

Reliability: When animals are on upland summer ranges, there is potential for surveys using some type of sampling design, but minimum count systems are not practical in most areas.

Fall Surveys

In the northern half of the region, Bergerud (1978a) identified and surveyed a minimum of 9 herds, including that in Spatsizi Park, and referred to small groups in a few other areas. Except for the Atlin Herd (above) all surveys involved fall rut counts as described for Spatsizi. The total distribution at the time of survey was not known for any of the herds/populations observed (Table 7: I.A).

Pros: Animals tend to aggregate into local, conspicuous concentrations (Table 8); often occurring in open, upland habitats (Table 8).

Cons: Groups mobile and unpredictable (Table 8); not all classes present in rut concentration areas (Table 7: I.C.1-3); patchy snow conditions often reduce sightability (Table 8); survey only of rut concentration areas amounts to only partial count in terms of herd/population total distribution (Table 7: I.B.4).

Reliability: Poor for both numbers and demography.

Omineca Sub-Region

In the south, King (1984) conducted late winter helicopter surveys in upper subalpine forests of the Cariboo Mountains, southeast of Prince George, obtaining much higher minimum estimates (animals seen plus those accounted for by tracks) for that area than were expected on the basis of incidental sightings during at least the previous decade. The author attributed the distribution that year to unusual snow conditions, and noted that the animals may be found in different habitats in late winter of different years. In that regard, therefore, the applicable pros, cons, and reliability of counts in that season are as outlined for the Telkwa and Tweedsmuir Circle Herds (Skeena Sub-Region), above.

In the north, only the Lawyers Pass caribou have been surveyed with any regularity, and that by the fall rut methodology. Accordingly, the assessment given above for fall surveys in the Skeena Sub-Region applies there as well. There have also been some winter surveys producing data on a few smaller herds in the northern Omineca Sub-Region (Bergerud 1978a; Anonymous 1983). The ranges, population affinities and usual winter distribution of those herds is not known (Table 7: I.A), thus the survey coverage has almost certainly been inadequate to determine total numbers (Table 7: I.B.4). Comparisons between the results of those surveys and fall survey results from either those areas

Appendix 5 (continued)

or from other northern herds are subject to most of the concerns listed under Item II in Table 7.

Peace Sub-Region

Bergerud (1978a) listed 16 herds for the area, mostly on the basis of known areas of fall occurrence. He flew extensively in February and early March 1978, but noted that survey results at that time were "disappointing" in that he failed to account for many of the animals expected. He recommended rut surveys and they apparently are now preferred in the Peace area (Anonymous 1983; Elliott 1985a), although some winter surveys are still conducted (Anonymous 1983; Elliott 1985b). The pros, cons, and expected reliability of the fall surveys in the Peace Sub-Region are as listed for other areas in northern British Columbia (see account for Skeena Sub-Region, above). As with other areas, the winter surveys are subject to the discrepancies caused by differential weather patterns (Table 7: I.B.1-3), and comparisons of winter and fall results are subject to the concerns listed under Item II, Table 7.

An incidental winter count in the Muskwa-Prophet Rivers area is of interest here in that it represents the largest total of caribou obtained in a single survey in British Columbia. During the period 17-21 January 1969, Luckhurst (1969) recorded 2675 animals in the uplands west of the Alaska Highway in that area. Such a degree of alpine occurrence at that time of year is unusual, and was clearly forced by weather conditions. It is unlikely that the numbers indicated involved only the local population, as interpreted by Bergerud (1978a). Rather, it was probably an artificial concentration also forced by that weather, through movements from other areas.

* * * * *

Copies of Wildlife Reports are available, depending on supply, from the British Columbia Wildlife Branch, Ministry of Environment and Parks, Parliament Buildings, Victoria, B.C. V8V 1X5.

No. R-1 Ungulate use of some recently reclaimed strip mines in southeastern British Columbia. E.A. Stanlake, D.S. Eastman, and M.G. Stanlake. February 1978. 82pp.

No. R-2 Effects of selective logging on arboreal lichens used by Selkirk caribou. S.K. Stevenson. November 1979. 75pp.

No. R-3 Seasonal movements of black-tailed deer on northern Vancouver Island. A.S. Harestad. December 1979. 98pp.

No. R-4 A history of the pheasant in the Okanagan Region of southern British Columbia. D.J. Spalding and R.P. Stoneberg. December 1981. 64pp.

No. R-5 A manual for the identification by epidermal characteristics of some forage plants species of the southern interior of British Columbia. B.M. Wikeem and M.D. Pitt. May 1983. 144pp.

No. R-6 The breeding ecology and management of white pelicans at Stum Lake, British Columbia. D.L. Dunbar. September 1984. 85pp.

No. R-7 Relationships among black-tailed deer population trends, winter range, hunting and wolves in the Nimpkish Valley, Vancouver Island. G.W. Jones and B. Mason. August 1983. 26pp.

No. R-8 Aspects of social organization and diurnal activity patterns of California bighorn sheep (Ovis canadensis california Douglas 1829). R. Eccles. October 1983. 71pp.

No. R-9 Foraging ecology and nutrition of Stone's sheep. D.R. Seip. October 1983. 127pp.

No. R-10 Wildlife habitat handbooks for British Columbia: problem analysis. A.P. Harcombe. April 1984. 237pp. (Also printed as MOE Tech. Rep. 8 and WHR-8).

No. R-11 Wildlife habitat handbooks for British Columbia: standard taxonomic list and codes of amphibians, reptiles, birds and mammals. R.W. Campbell and A.P. Harcombe. March 1985. 86pp. (Also printed as WHR-20).

No. R-12 Studies of radio-collared caribou in the Spatsizi Wilderness Park area, British Columbia, 1980-1984. D.F. Hatler. December 1986. 217pp. (Also printed as Spatsizi Association for Biological Research Rep. No. 3).

No. R-13 Nest tree selection by primary cavity-nesting birds in south-central British Columbia. D.G. Keisker. June 1987. 67pp.

No. R-14 Perspectives on inventory of caribou in British Columbia. D.F Hatler. July 1987. 104pp. (Also printed as Spatsizi Association for Biological Research Rep. No. 4).